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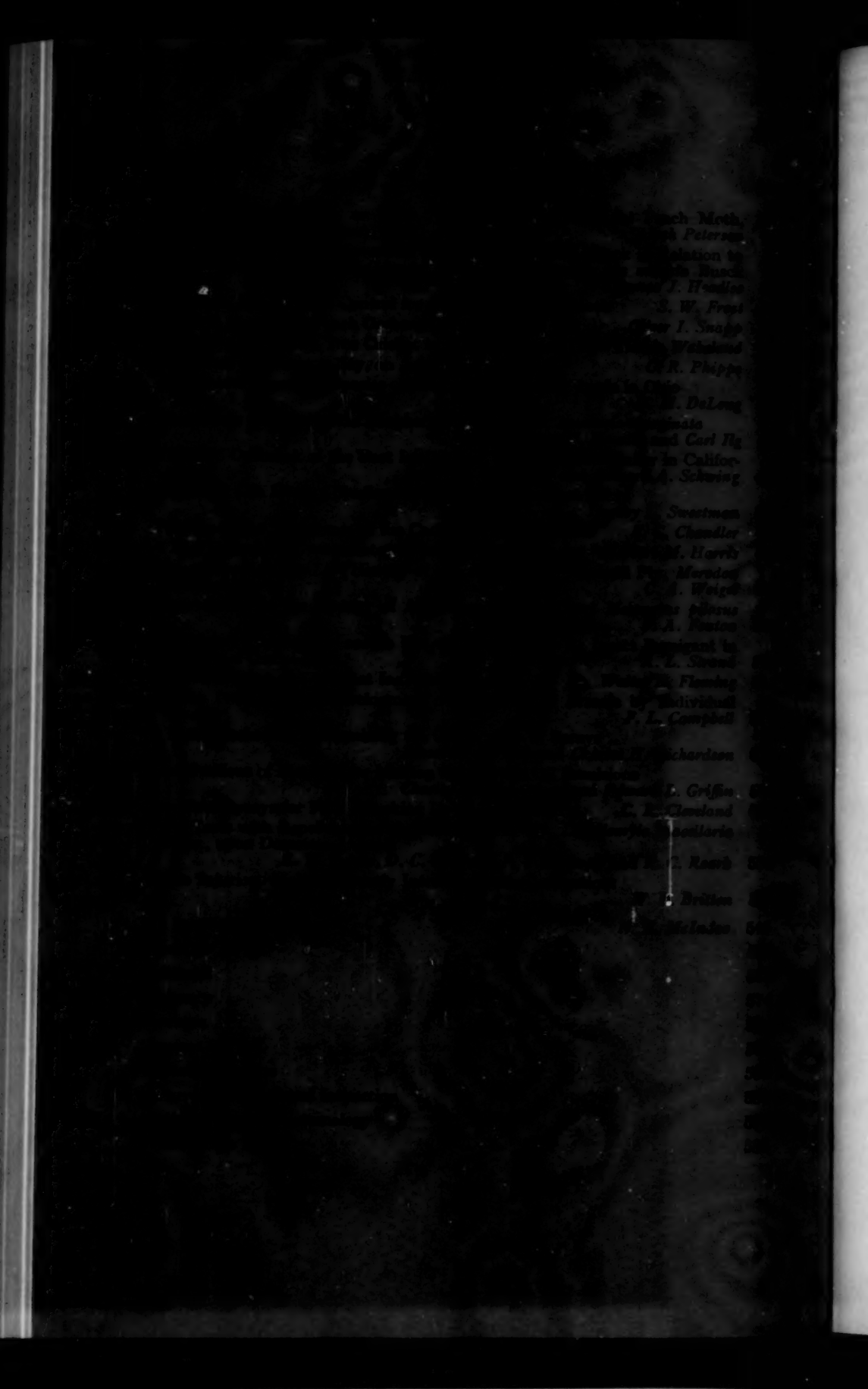

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ADDITIONAL INFORMATION ON BAITS ATTRACTIVE TO THE ORIENTAL PEACH MOTH, *LASPEYRESIA MOLESTA* BUSCK, 1925

By ALVAH PETERSON, *Entomologist, Fruit Insect Investigations, Bureau of Entomology, United States Department of Agriculture*

ABSTRACT

Oriental peach moths are attracted to fermenting molasses baits from the middle of April until the middle of October. Some or many males and females may be found in the bait containers every day during the entire season.

This year, 1925, at Riverton, New Jersey, the largest number of adults were captured during the emergence period of the first brood moths. Later broods were reduced by parasitism. The graphs show that more moths came to the same sort of bait located in peach orchards than in apple or quince orchards.

An enameled stewpan has proved to be the most satisfactory container for baits. So far as known bait containers should be well filled in order to catch the maximum number of adults. Containers placed high in the tree catch more moths than those placed low.

Cheap stock-feeding molasses seems to be the most satisfactory grade of molasses for baits. Dilutions of 1–10 and 1–20 are more satisfactory than weaker or greater strengths. Yeast is unnecessary. Under most conditions natural fermentation makes a better bait than where yeast is added. Corn syrup, particularly the colorless grade, diluted 1–20 with water, attracted large numbers of moths.

During 1925 the author continued to investigate problems associated with the oriental peach moth. The location of the work was primarily at Riverton, New Jersey. Particular attention was paid to baits attractive to the adults. This was a continuation and an enlargement of similar investigational work conducted at New Brunswick, New Jersey, in 1923 and 1924, a report of which may be found in the Journal of Economic Entomology for February, 1925.

ORCHARD RECORD

In order that a continuous record for an entire season on the attractiveness of a molasses-yeast bait might be had, bait pans were placed in several orchards about Riverton, New Jersey. All told, fifty bait pans

(Figure 13—type 1) in lots of ten were placed in several orchards between April 15 and 20 and permitted to remain until November 1. These pans were placed as follows: Ten in an old, neglected, bearing, quince orchard which was located several hundred yards from any peach

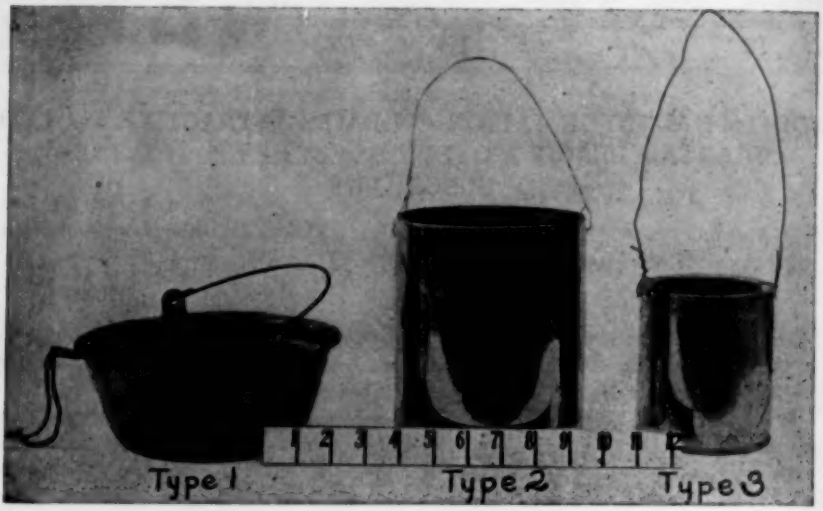

Fig. 13. Types of bait containers used and twelve inch rule for comparison.

orchards; ten in a block of 10 to 12-year-old Krummel peach trees and ten in a young bearing apple orchard which was located about 200 yards northwest of the Krummel peach trees, both orchards belonging to H. G. Taylor; ten in an old block of bearing Carmen trees and ten in a block of bearing Krummel trees, both blocks belonging to B. J. Lippincott. These two blocks were separated by a few rows of Elberta peach trees. A molasses-yeast bait, made from a good grade of table molasses and diluted 1–10 with water, was used in all of the fifty pans. One cake of moist, compressed yeast was thoroughly mixed with enough bait to fill ten pans. The same grade of molasses was used in refilling throughout the season.

So far as possible, the position of the bait pans in each unit of ten was approximately the same in every tree. They were placed five or six feet above the ground, on the same side of the tree, and one pan in every other tree in a continuous row. Observations were made in the morning hours and all of the captured insects were removed. From May 1 to August 20 the containers were examined each day, with a few

exceptions, including holidays and Sundays while before May 1 and after August 20 the examinations were made three times a week on Monday, Wednesday and Friday. On Mondays throughout the season approximately one tablespoonful of molasses was added to each bait pan. No new yeast was added. An effort was made to keep the pans three-fourths filled by adding water when needed.

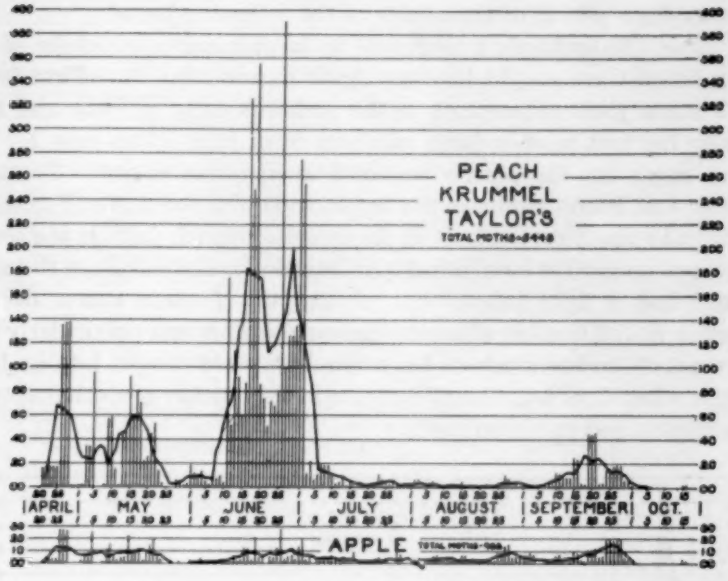

Fig. 14. A double chart showing the total daily catch of moths from ten bait pans in an apple orchard and ten bait pans in a peach orchard at Taylor's farm.

The five graphs (Figures 13 to 17) show the daily catch (perpendicular lines) of moths in the ten pans from each block of fruit trees. The heavy plotted lines on the charts are weekly or seven-day average curves. The location of the points of the curved line on each chart was obtained as follows. For any given date add to the total number of moths caught on that date the total number of moths caught the three preceding days and the three following days and divide the sum by seven. This gives a point which is the average of any seven-day or weekly period about any given date. It will be noted that an average curve of this type makes a fairly smooth line. It eliminates, in part, the decided daily variations in the catch brought about by changes in the weather and other factors.

The several graphs (Figures 13 to 17) indicate the comparative population of moths in the different orchards during the entire season. Possibly the most striking fact revealed is that some or many adults are present in peach orchards at all times from the middle of April to the middle of October. At no period is there a complete absence of moths. This information agrees closely with the life history studies in the insectary. Briefly stated the emergence period of the adults of each brood overlaps the emergence period of the adults of the following brood.

In all of the orchards a moderate to large number of adults of the spring brood were caught between April 15 and May 25. First brood adults made their appearance in the orchards early in June and they came to the bait pans in large numbers from June 10 to July 2. The largest catch for the season occurred during this period. The total catch of first brood adults in the apple and quince orchards (Figures 14 and 15) was small, particularly in the quince orchard. Late in the season the quince orchard showed a heavy infestation and the fruit in the apple orchard had a light infestation. After July 1 there was a decided reduction in the number of moths captured. This was particularly true in the peach orchards where large numbers were caught late in June. In September there was a small increase in the number of moths captured in the peach and apple orchards.

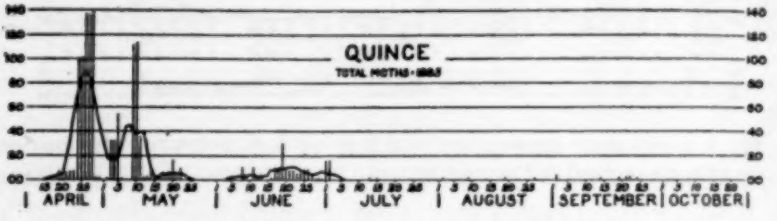

Fig. 15. Chart showing total daily catch of moths from ten bait pans in a quince orchard at Horner's farm.

The marked reduction in the number of moths captured during July and August was a complete surprise for in 1924 the maximum number of adults had been taken during these months. At first an explanation was sought for in the weather conditions prevailing during this period; also possible changes which might have taken place in the baits was looked into but neither gave a satisfactory solution of the problem. It is now believed, that in the parasite situation lies the answer. An examination of the parasite records showed that all of the weekly and more frequent collections of larvae taken from twigs on young peach

trees located near the bait pans showed some to high parasitism. From June 22 to August 20 all of the collections showed 50 to 100 per cent parasitism while collections made between June 22 and July 10 showed 90 to 100 per cent. The most important parasite was an undetermined species of Macrocentrus. Late in the season, during August and September, *Trichogramma minutum*, an egg parasite, was abundant

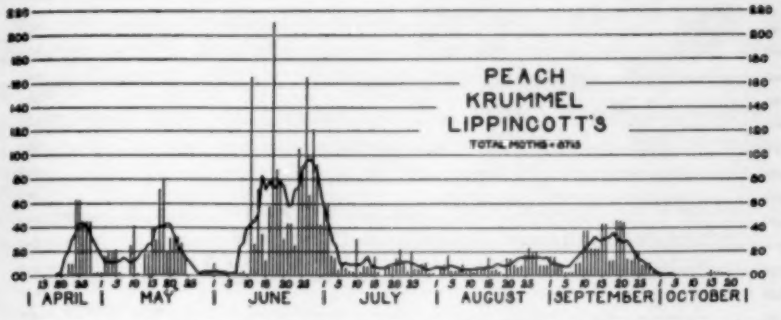

Fig. 16. Chart showing total daily catch of moths from ten bait pans in Krummel peach trees at Lippincott's farm.

in the eggs. In a few collections egg parasitism ran as high as 60 per cent. The small amount of infested fruit in the Riverton district this season also indicates that the parasite reduced the population of moths during July and August. Peach varieties, previous to and including Hale, showed 2 to 10 per cent infestation with one or two exceptions where Elberta peaches showed a 20 per cent infestation. Krummel peaches, however, in two orchards showed 75 to 90 per cent wormy fruit.

Comparing this year's results with those of 1924 where large numbers of adults were captured during July and August no parasitism record exceeded 15 per cent at New Brunswick, 1924. The above status of parasitism at Riverton and New Brunswick probably accounts for the decided difference in the relative number of adults caught in the bait pans during July and August in the respective localities.

Methods

In all of the bait experiments the different products tested were placed in five or ten containers. Large variations in the number of adults caught in the individual pans or pails frequently occur, consequently it is believed that a unit of five (ten is better) containers is the minimum number that should be used to obtain consistent or average results.

The position of the bait pans or pails in the trees in any series of tests should be as nearly uniform as possible. Generally, in the tests

the bait containers were placed among trees of one variety, in every other tree and usually in every other row. During most of the season the containers were examined daily or three times per week. Space will not permit a presentation of the numbers caught in individual pans or the total for each daily collection. The tables show the total catch for the period covered by each test.

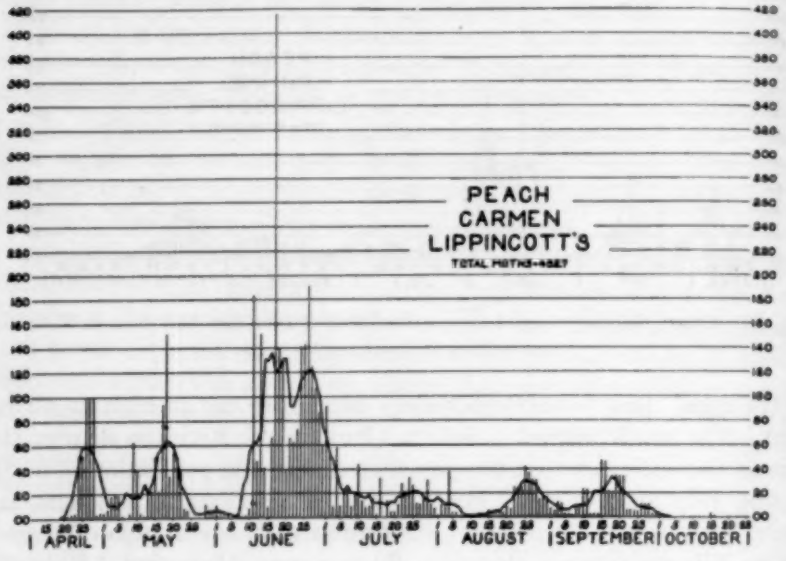

Fig. 17. Chart showing total daily catch of moths from ten bait pans in Carmen peach trees at Lippincott's farm.

Containers

Several types of traps and containers were constructed and tested in order to find the most desirable trap for the moths. So far no apparatus has been found which is as efficient as an open pan or pail filled with a liquid bait. The containers shown in figure 13 were used most extensively in the various tests. Type 1 is an enameled stewpan (capacity about three pints), type 2 a gallon tin can, and type 3 a quart tin can. Long wire bails were inserted on types 2 and 3. During the season a number of comparative tests were made with several baits to determine the relative efficiency of the respective types. Table 1 records some of the results obtained. In nearly every test the enameled stewpans, type 1, caught two to four times as many adult oriental peach moths as the large pails, type 2, or the small pails, type 3. In one test the small pails

caught more adults than the large pails or stewpans. In this particular test the difference in the total catch might have been due to the fact that the small pails were located in trees of a different variety than the other containers.

Amount of Bait

In collecting adults from the bait containers it was repeatedly noted that whenever the quantity of the liquid bait was low in a container a decided reduction in the number of adults captured in such pans or pails usually occurred. To test the value of this observation a few experiments were made with large pails, type 2, partly and nearly filled with bait. In one experiment ten pails were placed in five large bearing Krummel trees, two pails in each. One pail in each tree was one-fourth to one-third filled and the other pail two-thirds to three-fourths filled with bait. So far as possible these amounts were maintained throughout the duration of the test. Table molasses without yeast diluted 1–20 with water was the bait used.

Unfortunately the total catch in this test was not as large as desired owing to the scarcity of adults during the period of the experiment, July and August. Nevertheless there was a decided difference in the results obtained. The pails, which were two-thirds to three-fourths filled caught three times as many adults as the pails which were one-third to one-fourth filled. If further tests substantiate these results it will be necessary to keep the containers well filled with bait in order to catch the maximum number of moths.

Location of Containers

The location of the bait container in the tree appears to be important. The evidence thus far obtained indicates that the height of the container in the tree is the most important factor in respect to location. There is also some evidence to show that containers located in the shaded and central portion of the tree catch more adults than those exposed to sunlight and situated near the ends of the branches.

The importance of the height of the container in the tree was determined by several tests. In one, five pails, somewhat larger than type 3, were placed at five different heights in a large Krummel peach tree, thirteen feet high, situated near the northeast corner of a solid block of Krummel peach trees. The experiment was begun May 15 and ended October 30. The pails, at the outset, were filled with a molasses-yeast bait, table molasses, 1–20 and one cake of compressed yeast. During the period of the test every seven to ten days one tablespoonful of

molasses was added to each pail. Space will not permit a presentation of the interesting data shown in the daily catch. Table 2 shows for each container the height, the season's catch and the percentage of the total catch for the five pails. The results show a consistent increase in the total and the percentage of the total catch from the lowest to the highest pail. The highest pail caught more moths than all of the others combined.

In another test nine pails of type 3 were placed in three large Krummel trees. The three pails were placed in each tree at the heights indicated in Table 3. The bait used was a good grade of table molasses, diluted 1–20 with water and no yeast. In general, the results of this test agrees with that reported in Table 2. It will be noted that the total catch for the highest pails is not much greater than that for the middle pails. This may have been due to the fact that in this experiment it was almost impossible to keep the highest pails filled with bait at all times because of the high winds. The trees used in this test were not as large as those in the former test and this added to the difficulty. Probably a greater number of moths might have been captured in the high pails if more favorable conditions had existed.

The above tests and others of a similar nature convinced the author that the height of a bait container or trap in a peach tree is important for success in capturing adults. Generally speaking the higher the container the greater the catch. This conclusion is closely correlated with the observation that most of the moths fly about the tops of the trees.

Baits

Early in the season the investigational work on attractive agents was confined to molasses-yeast baits. Several tests were made with two grades of molasses to determine the most desirable dilution. The following dilutions being tried, 1–5, 1–10, 1–20, and 1–40. The results show that a 1–10 or a 1–20 dilution was usually as effective as greater concentrations while 1–40 was too dilute. A 1–20 dilution also proved quite satisfactory for corn syrup and honey when used as a bait.

In molasses-yeast baits concentrations greater than 1–20, particularly a 1–5 dilution, produced rapid fermentation which usually resulted in excessive foaming and the formation of scum over the surface of the liquid bait. This is undesirable because the maximum number of adults are caught where the surface of the liquid is free of solid matter.

Early in the season several comparative tests were made between molasses baits containing yeast and those containing none at the outset.

In almost every test the total catch of adults for the duration of the experiment was largest in the baits which contained no yeast when placed in the orchard. The most striking difference noted between the two baits was the length of time required for fermentation to start. Baits containing yeast begin to ferment almost at once and large numbers of moths may be attracted to the containers within three days, whereas baits containing no yeast when placed in the orchard require two or three days for wild yeast to start fermentation and it may be four to seven days before adults are attracted in large numbers to the bait.

The rate of fermentation of the different baits was determined by the amount of gas formed in glass fermentation tubes. Samples of bait were taken every 24 to 48 hours. A number of interesting facts were learned about gas production in the different baits, but these will not be reported here. One important fact, however, should be noted. The usual short duration, 48 to 96 hours, of the gas production indicates that the gas which passes off during active fermentation does not contain and include all of the attractive chemicals which draw the adults to the bait for after gas production ceases moths continue to come to the bait pans in considerable numbers. Frequently after all gas formation has ceased oriental peach moths are the only species of insect found in the baits.

There is considerable difference in the behavior and the resulting physical consistency of the several grades of molasses tested where yeast was added or omitted. In several experiments with one high grade, table, molasses the addition of yeast improved the physical consistency of the bait. Where no yeast was used in this molasses, 1–20 dilution, it became very thick and sticky within a few days. The sticky quality was desirable but the thickness of the liquid made it extremely difficult to clean out the insects captured. As a rule molasses baits with yeast omitted had the best physical consistency and captured the largest number of moths.

The results so far obtained indicate that the most satisfactory molasses bait is made from cheap molasses used in feeding stock. Mr. S. W. Frost suggests the addition of sodium arsenite to increase the effectiveness of a molasses bait. Several tests were made with stock-feeding molasses, 1–10 and 1–20 dilution, where sodium arsenite 5 or 7 grams, was added to each quart of bait. See Table 4 for some of the results obtained. In some cases an increase in the catch occurred and in others a reduction took place. The cause of this variation is unknown. It should be noted that the increase occurred where enameled pans of type 1 were used and a decrease took place where tin containers held the bait. In a number of

the tests, particularly in the tin pails, it was observed that a heavy green mould covered the surface of the baits containing sodium arsenite.

So far we have been unable to determine the chemical structure of the agent or agents in fermenting molasses-yeast baits which attracts the moths. It is probable that this point will not be determined until a trap is constructed which will catch and retain the adults or an apparatus is made which may be used in the laboratory. A goodly number of pure chemicals have been tried in various ways but so far the results have been negative.

Comparing in a general way the observations on the ratio of the sexes, the condition of the females, the habits and time of flight of the moths and other points of interest noted this season with those noted in 1924 a close similarity is apparent.

The use of a bait in the orchard as a means of control is still in the experimental stage. No comments or recommendations will be made at this time.

TABLE 1. RESULTS OBTAINED IN SEVERAL EXPERIMENTS WITH THREE TYPES OF BAIT CONTAINERS. (SEE FIGURE 13).

Number	Bait	Date of experiment	Orchard	Number of moths caught Type 1	Type 2	Type 3
1	Stock molasses, 1–20	July 27 to Aug. 31	W	1614	453	126
2	Stock molasses, 1–20	Aug. 31 to Oct. 5	W	1287	717	
3	Stock molasses, 1–20, and sodium arsenite 5 gm. per container	Aug. 6 to Oct. 2	L	330	81	3
4	Stock molasses, 1–20	Aug. 6 to Oct. 2	L	70	68	192

TABLE 2. MOTHS CAUGHT IN BAIT CONTAINERS AT FIVE DIFFERENT HEIGHTS IN A LARGE BEARING KRUMMEL PEACH TREE. A MOLASSES-YEAST BAIT USED. DURATION OF EXPERIMENT MAY 15 TO OCTOBER 30.

Number of pail	1	2	3	4	5
Feet above ground	2½	4	5½	7	9
Number of moths caught	39	70	166	429	816
Percentage of total of all pails	2.5	4.6	10.9	28.1	53.6

TABLE 3. MOTHS CAUGHT IN NINE SMALL PAILS, TYPE 3, PLACED IN THREE KRUMMEL PEACH TREES AT HEIGHTS INDICATED. THE THREE PAILS IN EACH TREE WERE FILLED WITH TABLE MOLASSES, 1–20. DURATION OF EXPERIMENT MAY 16 TO AUGUST 4.

Height of pails	Tree 1	Tree 2	Tree 3	Number of moths	Percentage
Low pails, 2 to 3 feet above ground	123	107	128	358	21.4
Middle pails, 5 to 6 feet above ground	190	212	238	640	38.3
High pails, 10 to 12 feet above ground	246	205	221	672	40.2

TABLE 4. RESULTS OF SOME OF THE BAIT EXPERIMENTS CONDUCTED DURING 1925. FIVE CONTAINERS WERE USED IN EACH TEST. SEE DISCUSSION ON METHODS.

Test No.	Bait	Period of test	Containers (see figures)	Orchard	Number of moths
1A	Stock molasses, 1–20	June 9 to Aug. 8	Type 1	L	1,560
2A	Stock molasses, 1–20, and yeast	June 9 to Aug. 8	Type 1	L	1,468
3B	Table molasses, 1–20	July 27 to Oct. 5	Type 2	W	961
4B	Stock molasses, 1–20	July 27 to Oct. 5	Type 2	W	1,170
5C	Table molasses, 1–10	June 12 to July 27	Type 3	T	310
6C	Stock molasses, 1–10	June 12 to July 27	Type 3	T	507
7D	Stock molasses, 1–20	Sept. 4 to Oct. 7	Type 1	L	103
8D	Table molasses, 1–20	Sept. 4 to Oct. 7	Type 1	L	76
9D	Dark corn syrup, 1–20	Sept 4. to Oct. 7	Type 1	L	182
10D	Honey, 1–20	Sept. 4 to Oct. 7	Type 1	L	68
11E	Stock molasses, 1–20, sodium arsenite, 7 grams to 2 quarts	Aug. 10 to Oct. 5	Type 2	W	128
12E	Stock molasses, 1–20	Aug. 10 to Oct. 5	Type 2	W	1,126
13F	Stock molasses, 1–20, sodium arsenite, 5 grams per pan	Aug. 4 to Oct. 9	Type 1	L	179
14F	Stock molasses, 1–20	Aug. 4 to Oct. 9	Type 1	L	103
15G	Stock molasses, 1–20, sodium arsenite, 7 grams per pan	July 22 to Oct. 2	Type 1	L	427
16G	Stock molasses, 1–20	July 22 to Oct. 2	Type 1	L	163
17H	Stock molasses, 1–20, sodium arsenite, 7 grams per pail	Aug. 1 to Oct. 2	Type 2	L	84
18H	Stock molasses, 1–20	Aug. 1 to Oct. 2	Type 2	L	49
19I	Stock molasses, 1–20, sodium arenite, 3.5 grams per pail	Aug. 3 to Oct. 2	Type 3	L	3
20I	Stock molasses, 1–20	Aug. 3 to Oct. 2	Type 3	L	192
21J	Cider vinegar, 1–1	June 9 to June 19	Type 3	T	16
22J	Sweet cider, 1–1	June 9 to June 19	Type 3	T	60
23J	Table molasses, 1–10, and yeast	June 9 to June 19	Type 3	T	34
24J	Table molasses, 1–10	June 9 to June 19	Type 3	T	110
25J	Water	June 9 to June 19	Type 3	T	1
26K	Table molasses, 1–10	June 19 to July 27	Type 3	T	272
27K	Table molasses, 1–20	June 19 to July 27	Type 3	T	233
28K	Table molasses, 1–40	June 19 to July 27	Type 3	T	188
29K	Water	June 19 to July 27	Type 3	T	5
30M	Light corn syrup, 1–10	Aug. 25 to Oct. 9	Type 1	L	501
31N	Dark corn syrup, 1–20	Aug. 18 to Oct. 5	Type 2	W	684

Note—A given series of tests is designated by a common alphabetical letter.

THE REGULATION OF THE MOVEMENT OF FRUIT AND NURSERY STOCK IN RELATION TO THE DISTRIBUTION OF THE ORIENTAL FRUIT MOTH (*LASPEYRESIA MOLESTA* BUSCK)

By THOMAS J. HEADLEE, Ph. D., *State Entomologist of New Jersey*

The oriental fruit moth may be carried on nursery stock, in fruit, in packages of various sorts, in railroad rolling stock and on or in any type of debris which has been within reach of the larvae at the time that they were spinning up. The oriental fruit moth may also move on the wing with the aid of air currents.

The number of oriental fruit moth larvae found on peach nursery stock is extremely small, but, owing to its wide distribution, should prove a factor worthy of consideration.

The amount of larvae moving in peach fruit is comparatively large but, of course, the chances for the survival of the larvae are relatively small.

The number of larvae moving in packages, containers, and other materials commonly shipped with peach fruit, while not as large as the number moving in fruit, is still of considerable size. Furthermore, the chances of these larvae surviving are much greater than the chances of those moving in the fruit. It is possible that freight cars, in which larvae have spun up, may carry the insect from one end of the country to the other.

Movement of the larvae of the oriental fruit moth in various kinds of debris must, necessarily, be limited in range, although it must be admitted that it is conceivable that such material might be carried under very unusual circumstances for long distances.

Natural movement of adult moths does, apparently, not exceed much over a mile, although in exceptional instances it is possible that they might be wind carried for considerably greater distances.

The problem of preventing the spread of this insect from an infested territory into an uninfested territory is, naturally, a difficult one and it is a grave question whether, using all the practical means within reach, its appearance in the uninfested territory can be long delayed. Certainly the prevention of the movement of peach nursery stock will not do it. The regulatory action must be broad enough to cover all the principal ways of distribution.

To cover the field thoroughly would mean an expenditure of large sums of money on inspection and the loss of a very large sum or sums to business interests, whose opportunity for marketing is, by this action,

curtailed. It should be remembered that this loss will be passed back, to a very large extent, to the growers and, in peach shortages, it will be passed on to the consumer.

Stating the matter frankly, there is a grave doubt in the mind of the writer whether regulatory action for preventing the spread of this insect is worth the time and trouble that it costs and the losses to the grower and consumer it entails. In fact, it is his considered opinion that public moneys spent upon finding efficient methods of controlling the insect will, in the long run, return to the public far better dividends than can be had through any regulatory action intended to delay spread.

BAIT-PAILS AS A POSSIBLE CONTROL FOR THE ORIENTAL FRUIT MOTH[1]

By S. W. Frost, *The Pennsylvania State College*

Abstract

This paper contains: (1) a report of a preliminary trial of the bait-pail method of control under orchard conditions; (2) the answers to certain questions concerning the feeding of females which are of importance to the problem; (3) a consideration of the best type of pail to maintain maximum catch and minimum evaporation; (4) a summary of numerous baits of the fermenting and non-fermenting types; and (5) a detailed study of the fermenting process in baits with special reference to their attractiveness to the oriental fruit moth, *Laspeyresia molesta* Busck.

The fact, well recognized by all oriental fruit moth investigators, that the four broods overlap completely, resulting in emergence of moths almost continually from the middle of April to the end of October depending somewhat upon seasonal conditions, and that egg-laying is an almost uninterrupted performance, led the writer to seek a method of control that would likewise be continuous. Previous investigations with bait-pails as a means of attracting the moths suggested a possible solution of the problem, namely, placing a sufficient number of pails containing an attractive bait in an orchard to catch the moths. During the summer of 1925 this was tried, and various phases of the problem were studied in some detail with the result that this method of control looks very promising.

A Preliminary Test of the Bait-Pail Method

A quince orchard was divided into two blocks. One block of 440 trees was equipped on May 18th with 170 tomato cans filled half

[1]Published by permission of the Director of the Agricultural Experiment Station as a part of Project No. 697. Contribution from the Department of Zoology and Entomology, The Pennsylvania State College, No. 401.

full with a mixture of one part molasses and five parts water. On June 26th the pails were refilled with the same mixture and on July 18th, gallon cans were substituted for the tomato cans and filled half full with a mixture of one part molasses, eight parts water and one ounce of sodium arsenite for every gallon of the mixture. A second block contained no pails during the summer.

On September first the quinces from the pailed and the unpailed blocks were examined and again on September 29th a second lot of quinces were examined. The results are summarized in the following table.

A SUMMARY OF THE ORIENTAL FRUIT MOTH COUNTS IN THE STEVESON QUINCE ORCHARD, MIDVALE, PA., 1925

		Number fruit examined	Number infested	Number worms	% infested fruit	% infestation
	Pailed Quince	269	149	156	53.3	57.9
Sept. 1	Block Unpailed Quince	276	206	265	71.0	96.0
	Block Pailed					
Sept.	Block	69	43	50	62.3	72.5
29	Unpailed	100	87	145	87.0	145.0

BAIT PAILS

Numerous types of containers were tried including tin cans and paraffined paper boxes, varying from a quart to a gallon capacity, with diameters from three to six inches. The maximum catch and minimum evaporation were secured by a container known by canners as a number ten tin-pail, having approximately a gallon capacity, a depth of seven inches and a diameter of six inches. Measurements of evaporation made during the dry period of the summer, favored this type of container. They were filled with about one quart of bait mixture, the upper portion of the pail serving as a sun shield and reducing the evaporation considerably.

BAITS

The ideal bait has not been fully determined. Field tests, where the bait is agitated each week in making collections, strongly favor the sodium arsenite, molasses and water bait. Such baits, however, when not disturbed for a period of a week or two, develop a dense growth of mould which decreases the effectiveness of the bait. At present a mo-

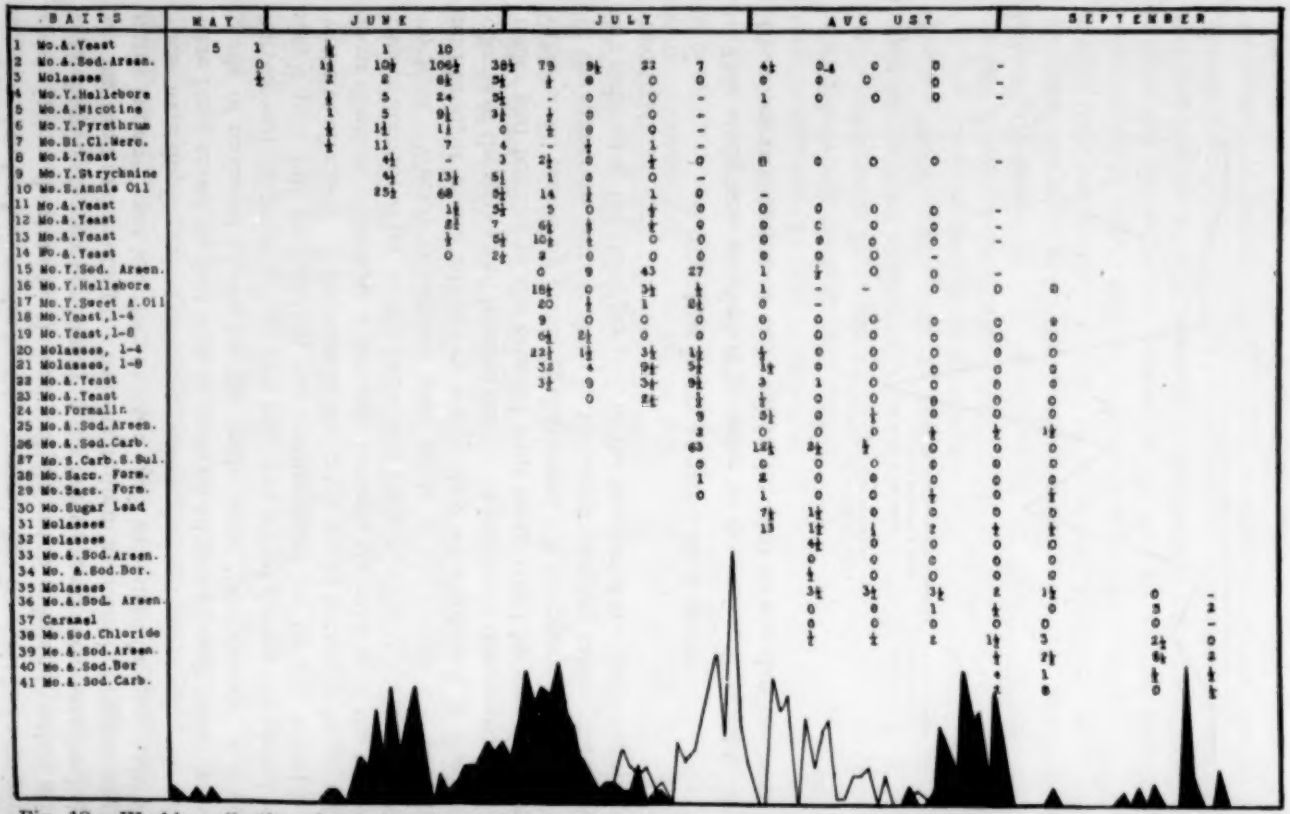

Fig. 18.—Weekly collections by various types of bait. All reduced to number of moths per pail. Graphs for emergence of moths during this period.

lasses and water bait works best for control, but its period of maximum catch is too short to be desired and its catch inferior to other baits.

Orchard tests were conducted in the following manner; standardizing the mixtures and making the tests as uniform as possible throughout the entire summer; not less than two test pails were used for each bait, and these were duplicated at different periods during the summer; the pails were hung about six feet high in pairs on adjacent peach trees; a good grade of molasses known by the trade name "Refodewah" was used throughout all the tests; no new bait was added during the period of a single pail, but evaporation was compensated for by the addition of water in all cases. A decrease in the catch would naturally be expected from dilution. Likewise a decrease towards the middle of the summer can be accounted for, as the pails were hung in a peach orchard bearing no fruit. Weekly collections were made of the contents of the pails, and brought to the laboratory where they were strained, washed, and counts of the males and females made. It was early discovered that the males and females of the oriental fruit moth could be separated from other small moths by genitalia characters. A summary of the catches of the numerous baits is given in the accompanying table. All catches are reduced to the catch per pail, as the number of test pails varied from two to six.

A Study of Baits at the Laboratory

This study was conducted in order to determine, if possible, what the attractive agents of baits might be, also to standardize baits for

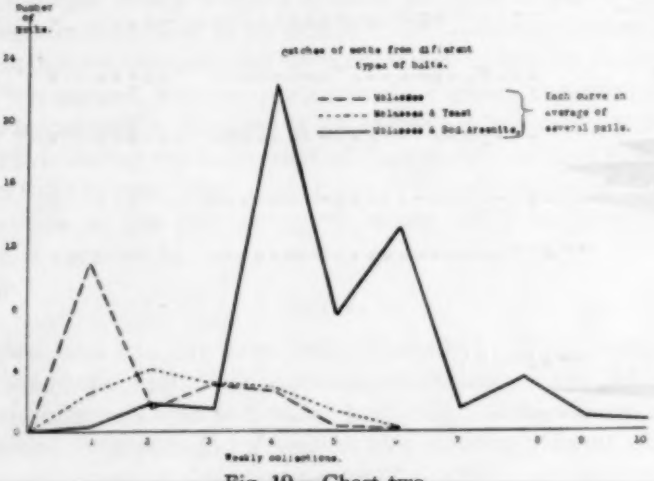

Fig. 19.—Chart two.

control work. The complexities of molasses and water baits are numerous, varying considerably as to the brand of molasses, the temperature and moisture conditions in the orchard, and pollution by wild yeasts, bacteria and fungi.

Commercial yeasts were used at first, but later discarded as useless, because wild yeasts are always present in quantities sufficient to start the fermentation process.

Laboratory tests were conducted along three lines; (1) the evolution of gas during the primary process of fermentation; (2) the production of alcohol; and (3) the production of acids and their atrophy during the secondary process of fermentation.

The evolution of gas was determined by means of fermentation tubes. Two or three samples of each bait were tested, and the averages of these were used in constructing the graphs. No attempt was made to separate the amount of hydrogen and carbon-dioxide evolved, as neither seemed to have any profound bearing on the problem. The tests were conducted in the laboratory and subjected to changes in temperature, but all series of tests, as the evolution of gas from different brands of molasses, were conducted at the same time, so that the results are comparable. A thermostat was placed in the midst of the fermentation tubes, giving a complete record of the temperature changes. The evolution of gas is rapid, sometimes reaching its maximum in forty-eight hours. Yeasts naturally hasten the process.

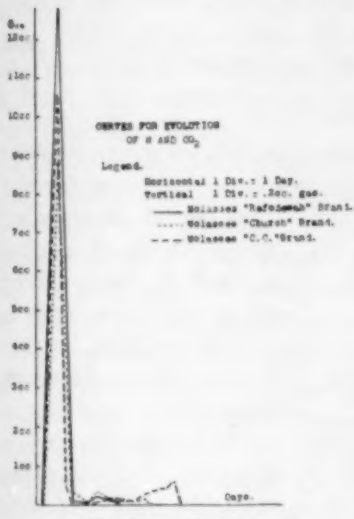

Fig. 20.—Chart three.

The production of alcohol was determined by a round-about but simple means. Specific gravity readings were taken at regular intervals. The specific gravity in freshly mixed baits ranged between 1050 degrees and 1040 degrees at 20 degrees centigrade. The sugars of the molasses contributed largely to this. The sudden reduction in the specific gravity is due to the production of alcohol. This is very rapid, and occurs simultaneous with the evolution of hydrogen and carbon dioxide. The specific gravity sometimes reaches 1000 degrees or even drops slightly below 1000 degrees. Following this sudden drop it rises slowly,

due to the production of acids, and also to evaporation, the latter a factor which could not be prevented.

The production of acid was determined by daily titrating samples of the baits. For convenience and accuracy the bait was diluted 50% with distilled water, and titrated against a 1% NAOH solution. The acids, even at the height of their production, are not strong. The readings are merely relative, but give a fine index of acid formation. Acid production begins soon after the evolution of gas ceases, and rises rather quickly, and then falls away gradually.

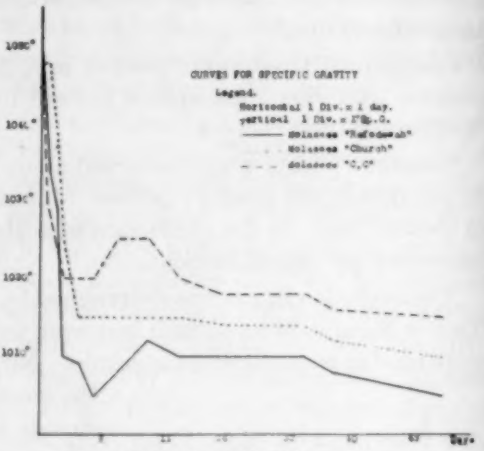

Fig. 21.—Chart four.

From these studies the writer deducts the following conclusion: alcohol cannot be the only attractive agent in fermenting baits, for the period of attractiveness would be very brief. This period, as revealed by the graphs of alcohol production, lasts from one to five days, and in very active baits, reaches its maximum in 24 hours. The same conclusion holds for the evolution of gases. On the other hand, the period of acid formation is very long, continuing for at least 50 or 60 days, and in some baits for 90 days. Orchard tests illustrated by the accompanying graphs show that freshly mixed baits attract almost immediately when placed in

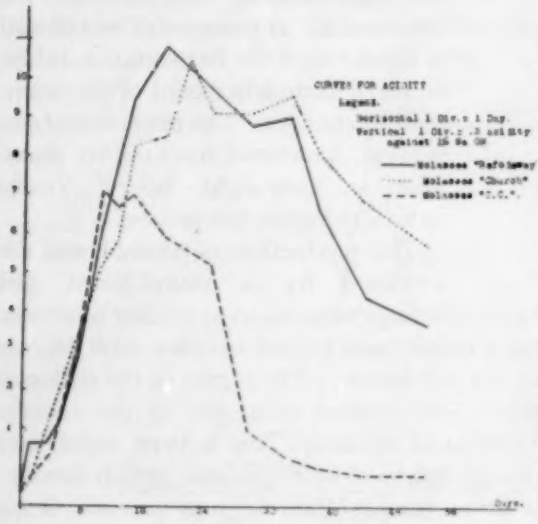

Fig. 22.—Chart five.

the orchard. This initial catch is probably due to the production of alcohol. Such baits continue attractive after the alcoholic production has ceased. There can be no doubt, therefore, that both alcohol and the acids are attractive agents in these baits.

Field and Laboratory Studies of the Adults

There is no doubt that the moths can be caught abundantly by bait-pails placed in peach or quince orchards. Whether or not some moths feed at pails, and succeed in making their escape has not been determined, but the numbers that have been caught seem sufficient to materially reduce the number of moths in an orchard. The writer has taken as many as 106 moths from a single pail in a week's collection from an orchard with a medium infestation.

Both the males and the females are attracted in approximately the same number, although the males occur more abundantly during the first part of the brood, while females occur more abundantly during the latter part of the brood. The attractiveness varies with different baits, but the principle of the trapping lies in the explanation given by Peterson (1925[1]), that the moths are unable to free themselves from the surface of the bait after feeding.

That the females, for the most part, feed before ovipositing, and that this feeding is not sporadic or accidental, but determined and apparently necessary for the moths, has been determined in three ways: (1) by records of the feeding activities of pairs of moths in captivity; (2) by records of the feeding activities of newly emerged females; and (3) by the dissection of females caught in bait-pails in the orchard.

Several laboratory experiments were conducted to determine the feeding activities of males and females. The moths were placed in eight-ounce, wide-mouthed bottles covered with gauze. They were fed daily with sugar solution. Notes were taken each morning after the sugar solution had been admitted. With a hand lens it was not difficult to discern the short proboscis of the moth inserted into the drop of sweetened solution, and the movements of the proboscis gave evidence of feeding. When a moth was observed feeding, a record was made to that effect. Sometimes it was necessary to watch a moth for fifteen or thirty minutes before feeding commenced, but as a rule the moths quickly detected the presence of the sugar solution and fed greedily. How many times the adults fed when not under observation could not be determined, but the records are sufficient to show that feeding, especially in the case of the females, is quite regular. The accompanying table

[1]Jl. Econ. Ent. 18, 1925.

summarizes the feeding activities of a number of moths. It is to be regretted that more eggs were not laid, but there were many conditions accountable for this that were not learned until too late.

TABLE SHOWING FEEDING PERIODS OF FEMALES*

Experiment number	Number females	Number times seen feeding Prior to Oviposition	Subsequent to Oviposition	Number eggs laid
1	1	1	0	6
2	1	1	0	103
3	1	2	0	0
4	1	2	0	0
5	2	6	0	0
6	2	3	0	0
7	3	1	0	0
8	1	7	0	0
9	1	1	0	0
10	1	6	0	0
11	1	3	0	0
12	2	0	1	31
13	1	3	0	0
14	1	3	0	0
15	1	2	0	0
16	1	2	0	0
17	1	2	0	0
18	1	3	0	0
19	1	4	0	0
20	1	3	0	0
21	1	1	0	0
22	1	1	2	31
23	1	1	0	38
24	1	0	2	18
25	1	3	0	0
26	1	2	0	0
27	1	1	1	1
28	1	2	0	0
29	1	4	0	0

*This table is greatly condensed from a large table showing the time and feeding periods of both males and females.

The fact that newly emerged moths eagerly and diligently seek sugar solution is good evidence that the females feed before ovipositing. One who handles the moths daily is strongly impressed by this fact. It is certainly apropos to say that the moths like sugar solution as a child likes candy. When a camel's hair brush previously dipped in a sweetened solution is lowered in a cage containing several newly emerged moths, almost without exception they will sense the presence of food. This is manifested by uneasiness on the part of the moths, and wander-

ings about the cage until the solution is found. Often the moths will congregate on the brush, and it is almost impossible to dislodge them. The writer has seen a moth drink an entire drop of sweetened solution placed on the side of a bottle.

Possibly the best index as to the time of feeding in reference to oviposition was secured by dissecting females collected from bait pails hung in the orchard. These records are summarized in the following table. The number of eggs present in the females was counted except when the ovaries showed an undeveloped condition, in which case it was evident that no eggs had been laid.

CONDITIONS OF OVARIES OF FEMALES TAKEN FROM BAIT-PAILS

Date collected from pail	Number of females	Compliment of eggs laid			
		None laid	½*	¾†	All laid
May 18	11	0	2	9	0
May 26	4	3	0	1	0
May 27	16	5	4	6	1
June 17	20	15	0	5	0
July 7	20	9	0	4	7
July 22	10	8	0	1	1
July 28	10	0	0	7	3
Sept. 22	20	11	8	0	1
Oct. 9	2	0	1	1	0
Total	113	51	15	34	13

*One-half compliment about 80 to 100 eggs.
†Three-fourths compliment about 150 to 160 eggs.

SUMMARY

(1) The bait pail method under orchard conditions reduced the percentage of infestation nearly 50%, and the percentage of infested fruit nearly 25%.

(2) A pail of approximately a gallon capacity, with a six inch diameter, filled with about a quart of bait, gave maximum catch and minimum evaporation.

(3) Fermenting baits are complex, uncertain, and soon become putrid. Nevertheless they, at present, work the best under orchard control conditions.

(4) The addition of commercial yeasts is not necessary, as wild yeasts are present in sufficient quantities to produce fermentation.

(5) The attractiveness of a fermenting bait is due to the presence of alcohol and acids. The evolution of hydrogen and carbon dioxide may also play a minor part.

(6) Non-fermenting baits are far more attractive than fermenting baits, but at present are not practical under orchard control conditions.

(7) Certain antiseptics as formalin and sodium salts arrest the fermentation process for a considerable period of time.

(8) Females are attracted to baits as readily as males.

(9) The females feed largely before ovipositing.

(10) Many conditions detract from the effectiveness of baits as (1) evaporation, (2) excessive rains, (3) contamination by Noctuids and other insects during certain periods of the summer, (4) contamination by bacteria, (5) growth of moulds upon the surface of the pails.

(11) A satisfactory bait has by no means been developed.

AIRPLANE DUSTING OF PEACH ORCHARDS

By OLIVER I. SNAPP, *in Charge, U. S. Peach Insect Laboratory, Fort Valley, Georgia*

ABSTRACT

Preliminary test flights with an airplane equipped for dusting cotton with calcium arsenate showed that it would not uniformly distribute the heavier dust used in treating peach orchards. As a result of work at Tallulah, La., airplane cotton dusters were made to handle the peach dust in a satisfactory manner by doubling the agitation in the hopper and by cutting down the outlet valve in order to reduce the flow of dust. Chemical tests showed that the active ingredients of this dust were fairly equally distributed to all portions of the dust cloud as it left the airplane. About 1,000 acres of peach orchards were commercially dusted from airplanes in Georgia in 1925, and under existing conditions the quality of the fruit from these orchards equaled that from orchards dusted by terrestrial machines. The ships flew from 10 to 20 feet above the trees at a speed of about 85 miles per hour, dusting the orchards at the rate of about 5,000 trees per hour. The dust swath width was about 60 feet, and the dust was applied at the rate of from $^1/_5$ to $^1/_4$ pound per tree. Four applications of dust were given. Experiments to determine the effectiveness of airplane dusting were conducted in four orchards. The results of cutting drops and harvested fruit from each of these orchards showed that under the conditions which prevailed in Georgia last summer airplane dusting was just as effective in controlling the curculio as was ground machine dusting. Tables are given in which the results of these experiments are reported. Colorimetric tests showed that arsenate of lead in a dust mixture was distributed somewhat better over the foliage of peach trees when dusted from an airplane than when dusted from a terrestrial machine. All of the results given should be accepted tentatively, since further experimentation, under varying conditions of climate and infestation, is needed before the efficacy of airplane dusting of peach orchards can be definitely established.

As a result of successful attempts during recent years to dust forest trees and cotton from an airplane to control insect pests, it occurred to the writer in the summer of 1924 that this instrument for distributing

dust might be employed in treating peach orchards for the pests that directly attack the fruit or foliage. Consequently, in November, 1924, a Huff-Daland, model 5, airplane duster was brought to Fort Valley, Ga., for some preliminary work looking to the dusting of peach orchards in the Georgia Peach Belt. This ship was equipped to distribute calcium arsenate and had been used for dusting cotton. Preliminary test flights using our peach dust consisting of 80% superfinely ground sulphur, 5% arsenate of lead, and 15% hydrated lime were very unsatisfactory, clearly demonstrating that the ships as they were equipped could not be used for peach orchard dusting. Since the peach dust was much heavier than calcium arsenate, it flowed from the hopper in a very irregular manner, resulting in an uneven distribution over the orchard. At times large puffs of the dust would be discharged and a few seconds later the dust cloud would be very thin. Considerable clustering of the dust particles was also noticed on the ground between the trees.

The solution of this problem was evidently either an adjustment of the feeding mechanism of the airplane dusters, so that they would discharge the heavy peach dust in a uniform manner, or the perfection of a lighter peach dust. Considerable time was spent and many test flights and adjustments were made in January and February, 1925, at Tallulah, La., where the facilities of the Delta laboratory and the assistance of Messrs. B. R. Coad and Elmer Johnson, who had previously had experience in dusting cotton by airplanes, were extended. After considerable experimentation, in which materials of different densities were used, the problem was solved by doubling the agitation in the hopper and reducing the rate of discharge of the dust by cutting down the outlet valve about one-half. With this adjustment the airplane discharged in a satisfactory manner peach dust of the density that had been used in ground machines in Georgia for years. Chemical tests showed that the active ingredients of the peach dust were fairly equally distributed to all portions of the dust cloud, and that there was no separating out of any of the ingredients, as is the case with some dust mixtures when distributed from an airplane.

Commercial Airplane Peach Dusting in Georgia in 1925

The Huff-Daland Co., of Ogdensburg, N. Y., airplane manufacturers, built five or six ships containing the equipment for dusting peach orchards which was perfected during the winter at Tallulah. In March these airplane dusters were brought to Montezuma, Georgia, for the purpose of dusting peach orchards on a commercial scale in that locality.

The company furnished the planes and service, and the growers furnished the dusting material. Charges for the planes and service were fixed at a rate per hundred trees. This rate was based on the cost of applying the dust by ground machines, and was very close to that figure. The company had no figures on the cost of dusting trees from airplanes, and in order to get this information and to establish the method, they were satisfied to contract for the work at actual cost of operating the planes plus depreciation.

Ninety-six thousand five hundred trees distributed over nearly 1,000 acres were given the first application of dust by airplane in the Montezuma section last March. Incidentally, this is the first record of dusting peach orchards from an airplane. The acreage receiving the second application by airplanes was not quite so large, but 115,000 trees received the third dusting and around 100,000 trees received the fourth. These acreages were dusted each time by two airplanes within four days. The 0–5–95 dust, consisting of 5% arsenate of lead and 95% hydrated lime, was used for the first and second applications, and the 80–5–15, consisting of 80% sulphur, 5% arsenate of lead, and 15% lime, for the third and fourth. The outlet valve in the hopper was set so as to release the dust at the rate of about one-fifth of a pound per tree when the 0–5–95 was being used, and at the rate of about one-fourth of a pound per tree when the 80–5–15 was used. Experimentation had shown that these are about the proper dosages for best results when ground machines are employed for distributing the dust.

This commercial airplane dusting was done at the rate of about five thousand trees per hour, including the time necessary to make trips to the landing field for refilling the hopper and for refueling, repairs, etc. In some cases the landing field was seven miles from the orchard. The outlet valve was about ¾ open when the 0–5–95 dust was being used and about ½ open when the heavier 80–5–15 was used. The swath width in most cases was about 60 feet, or three tree rows. There was usually a drift of the dust for a half dozen or more rows beyond the swath width. This, of course, depended on the wind velocity at the time of dusting. With this swath width and valve setting the desired dosage was usually distributed. During dusting operations the planes flew from ten to twenty feet above the tree tops. The dusters were one-man ships driven by Wright, J-4 model, 9 cylinder engines. The pilot operated both the ship and the hopper which is situated just in front of the pilot's cockpit, the outlet valve being regulated by a lever in the cockpit. The hopper is rectangular

in shape and has a top that can be readily opened for loading, and an outlet for the dust at the bottom. The dust falls into the rear of the throat of an air scoop as it is liberated from the airplane. A speed of from 85 to 90 miles per hour was maintained during dusting operations, and no difficulty was experienced by the pilot in operating both the ship and the feeding mechanism of the hopper.

Results of Commercial Airplane Dusting

Unfortunately the method did not have a very severe test during the 1925 season. Weather conditions were unfavorable for the development of both curculio and brown-rot. A precipitation deficiency had occurred since the first of the year, and the drought and very hot weather during the summer prevented many curculio pupae from developing in the soil, and likewise materially affected the development of brown-rot infections. Under the existing conditions the fruit from the orchards that were dusted from airplanes compared very favorably with that from orchards dusted from ground mule-drawn machines. The color of the airplane-dusted fruit was just as good, curculio and brown-rot were as well controlled, as much merchantable fruit was obtained, and reports from Eastern and Northern markets showed that the carrying quality was equally as good. These results, however, should be accepted tentatively, for several years experience with airplane dusting in orchards under varying conditions of weather and infestation will be necessary in order to ascertain the relative merits of this method of insecticide distribution.

Drawbacks to Commercial Airplane Dusting of Orchards

The season's work revealed several drawbacks to the dusting of fruit orchards by airplanes on a commercial scale. The capacity of the hopper carried in the airplanes was 600 pounds of dust, and on account of the comparatively heavy dose required per tree very frequent trips to the landing field were necessary to refill. This increased the expense of the method, especially if the orchard was far from the landing field. This defect could be corrected by increasing the capacity of the hopper, which would require a larger ship, or perhaps by increasing the percentage of the poison in the dust mixture and reducing the poundage per acre.

Another feature that augments the cost of the method is the fact that the landing field is not always accessible to the orchards. Practically all of the orchards that were dusted in the Montezuma section were handled from a field adjoining the city of Montezuma, which served as an operat-

ing base. Some of the orchards dusted were seven miles from this field. Much time can be saved and the method made more economical if landing fields are situated near the orchards to be treated.

Experiments to Determine the Effectiveness of Airplane Dusting

Four peach orchards were selected at Montezuma for experimental work to determine the effectiveness of airplane dusting as compared with ground machine dusting. Two of these orchards were given the usual four applications of dust, two of 0–5–95 and two of 80–5–15, from airplanes, and the other two were dusted by ground machines at approximately the same times with the same materials. One of the orchards treated from airplanes contained 10,000 trees, and the other 4,000. Both of the orchards dusted by ground machines were sizeable. All four orchards contained peaches of the Hiley and Elberta varieties, and results were taken on both varieties at each place.

The airplane dusting in these orchards was done with a Huff-Daland, model 5, duster driven by a Wright J-4, 9 cylinder motor. A speed of about 85 miles per hour was maintained during dusting operations. The dust swath width was about 40 feet for the 0–5–95 and 60 feet for the 80–5–15. The 0–5–95 was distributed at the rate of about $^1/_5$ pound per tree, and the 80–5–15 at about ¼ pound per tree. During the first dusting 5,833 trees were dusted from the airplane in 1 hour and 3 minutes. This included time for trips to the landing field to refill the hopper, repair, etc. The 10,000-tree orchard was dusted the second time in 1 hour and 33 minutes (actual flying time), and 2,100 pounds of the 0–5–95 was discharged over the orchard during that time. The 4,000-tree orchard was dusted the second time in 36 minutes (actual flying time), 800 pounds of 0–5–95 being used. All of the applications from the airplane were made at a speed of around 5,000 trees or more per hour.

In the two experimental orchards treated from ground machines the 0–5–95 was used at the rate of about $^1/_5$ pound per tree and the 80–5–15 at the rate of about ¼ pound per tree at each application, the same as used on the airplane-dusted orchards. About 4,000 trees per 10-hour day can be dusted by each ground machine.

Airplane vs. Ground Machine Dusting

Results on the comparative merits of the two methods of distributing dust to peach orchards for the control of the curculio were determined from both the drops and the harvested fruit. Three collections of peach drops were made in each of the two airplane-treated orchards and

the two ground machine-treated orchards. These were cut open to determine the percentage of curculio infestation. Five thousand drops gathered from beneath trees in all parts of the orchard were collected from each orchard on April 23 for the first examination. The second collection was made on April 30, when one thousand drops were taken from each orchard, and the third collection, consisting of the same number of drops, was made on May 7. Previous experiments had shown that three collections of drops timed one week apart, starting when a goodly number are down, would get around 90% of all the infested drops that fall during the season. The results of examinations to determine the degree of curculio infestation of the drops from each orchard are given in Table 1.

TABLE 1. RESULTS OF EXAMINATIONS MADE TO DETERMINE THE COMPARATIVE CURCULIO INFESTATION OF PEACH DROPS COLLECTED FROM ORCHARDS DUSTED BY AIRPLANE AND GROUND MACHINE, RESPECTIVELY, AT MONTEZUMA, GA. 1925.

Orchard No. and Method of Applying dust	Percentage of curculio infestation			
	1st collection	2nd collection	3rd collection	Average for the three collections
Airplane-dusted orchard No. 1	19.44	8.9	3.9	10.7
Airplane-dusted orchard No. 2	24.28	11.1	9.7	15.0
Ground-machine dusted orchard No. 1	8.34	19.9	3.8	10.7
Ground-machine dusted orchard No. 2	15.32	2.6	2.7	6.9

Average curculio infestation of peach drops from the two airplane-dusted orchards = 12.8%.

Average curculio infestation of peach drops from the two ground machine-dusted orchards = 8.8%.

For data on the comparative curculio infestation of the harvested fruit five trees were selected in different parts of both the Hiley and Elberta sections of each orchard. These were tagged and marked by a strip of white cotton cloth around the outside to prevent the fruit from being picked for commercial purposes. The fruit from these trees was harvested as it ripened, and each peach cut open to determine the cur-

TABLE 2. RESULTS OF EXAMINATIONS OF HARVESTED FRUIT FROM FIVE TREES IN EACH AIRPLANE- AND GROUND MACHINE-DUSTED PEACH ORCHARD MADE TO DETERMINE THE COMPARATIVE CURCULIO INFESTATION. HILEY VARIETY. MONTEZUMA, GA. 1925.

Orchard No. and method of applying dust	Number ripe peaches cut open and examined	Percent of fruit infested by curculio
Airplane-dusted orchard No. 1	1,900	0.2
Airplane-dusted orchard No. 2	2,365	0.3
Ground machine-dusted orchard No. 1	2,266	0.7
Ground machine-dusted orchard No. 2	1,761	1.4

culio infestation in the several orchards. Tables 2 and 3 give the results obtained from examinations of harvested fruit of the Hiley and Elberta varieties in each of the four orchards.

TABLE 3. RESULTS OF EXAMINATIONS OF HARVESTED FRUIT FROM FIVE TREES IN EACH AIRPLANE- AND GROUND MACHINE-DUSTED PEACH ORCHARD MADE TO DETERMINE THE COMPARATIVE CURCULIO INFESTATION. ELBERTA VARIETY. MONTEZUMA, GA. 1925.

Orchard No. and method of applying dust	Number ripe peaches cut open and examined	Percent of fruit infested by curculio
Airplane-dusted orchard No. 1.....	1,007	1.7
Airplane-dusted orchard No. 2.....	1,284	0.2
Ground machine-dusted orchard No. 1	1,221	2.8
Ground machine-dusted orchard No. 2	2,903	0.2

The average curculio infestation of the harvested Hiley fruit from the two orchards treated by airplane was 0.25 per cent, as compared with 1.05 per cent average infestation in the two Hiley orchards treated by ground machines. In the Elberta orchards the average curculio infestation of the harvested fruit treated by airplane was 0.95 per cent as compared with 1.5 per cent average infestation in the two Elberta orchards treated by ground machines. Although the curculio infestation of the drops from the orchards treated by airplane was a little higher than the drop infestation in the orchards treated by the other method, Tables 2 and 3 show that at harvest the curculio infestation was a little less in the orchards dusted from airplanes than in those dusted from ground machines. Therefore, under the conditions existing in central Georgia in 1925 it may be said that the airplane dusting was as effective in controlling the curculio in peach orchards as the ground machine dusting. However, as was pointed out in the discussion of the results from the commercial airplane dusting, the results from these experiments must be accepted tentatively, since further experimentation under varying conditions of weather and infestation is necessary before the relative merits of the use of the airplane for dusting peach orchards can be definitely established.

COLORIMETRIC TESTS TO DETERMINE THE DISTRIBUTION OF LEAD ARSENATE ON PEACH LEAVES FROM ORCHARDS DUSTED FROM AIRPLANES AND FROM GROUND MACHINES

In order to learn something of the distribution and quantity of lead arsenate falling on peach trees when dusted by airplanes as compared with terrestrial machine dusting, a number of leaves were collected in four orchards for colorimetric tests, as developed by Hamilton and

TABLE 4. RESULTS OF COLORIMETRIC TESTS TO DETERMINE THE DISTRIBUTION OF LEAD ARSENATE ON PEACH LEAVES DUSTED FROM AIRPLANES AND FROM GROUND MACHINES, RESPECTIVELY. MONTEZUMA, GA. 1925.

Orchard No. and method of applying dust	Date and time of application	Date and time of test	Leaves tested	Distribution of lead arsenate on leaves		Distribution of lead arsenate on leaves expressed in terms of percentages	
				Upper surface	Under surface	Upper surface	Under surface
Airplane-dusted orchard No. 1	June 13, morning	June 13, 12:30 P. M.	75	74 completely covered 1 partially covered	24 completely covered 50 partially covered 1 none	98.7% of leaves completely covered 1.3% of leaves partially covered	32.0% of leaves completely covered 66.7% of leaves partially covered 1.3% of leaves contained no poison
Airplane-dusted orchard No. 2	June 12, morning	June 12, 3:00 P. M.	31	22 completely covered 8 partially covered 1 none	19 completely covered 10 partially covered 2 none	71.0% of leaves completely covered 25.8% of leaves partially covered 3.2% of leaves contained no poison	61.3% of leaves completely covered 32.3% of leaves partially covered 6.4% of leaves contained no poison
Ground machine-dusted orchard No. 1	June 2, afternoon	June 2, afternoon	27	20 completely covered 5 partially covered 2 none	6 completely covered 16 partially covered 5 none	74.1% of leaves completely covered 18.5% of leaves partially covered 7.4% of leaves contained no poison	22.2% of leaves completely covered 59.3% of leaves partially covered 18.5% of leaves contained no poison
Ground machine-dusted orchard No. 2	July 1, morning	July 1, afternoon	45	22 completely covered 12 partially covered 11 none	18 completely covered 18 partially covered 9 none	48.9% of leaves completely covered 26.7% of leaves partially covered 24.4% of leaves contained no poison	40.0% of leaves completely covered 40.0% of leaves partially covered 20.0% of leaves contained no poison

Smith.[1] The leaves were collected by a person walking diagonally across the orchard from one corner, gathering leaves at random from different trees.

Tests were made from leaves collected in two orchards treated by airplane and two treated by ground machines. Table 4 gives the results of these tests.[2]

These tests show a better distribution of lead arsenate over the foliage in the orchards dusted by airplane than in those dusted from the ground. Numerous field observations also indicated a somewhat better distribution of dust in the airplane-treated orchards than in those dusted from the ground. Unfortunately, all of the orchards from which leaves were taken for colorimetric tests could not be dusted on the same day; nevertheless, each was treated under weather and other conditions considered favorable for either airplane or ground machine dusting.

Conclusions

Definite recommendations on the subject of airplane dusting in peach orchards cannot be made until this new method of applying insecticides has been tested under varying conditions of weather and infestation, but the following tentative conclusions have been reached:

1. Airplane dusters equipped for dusting cotton with calcium arsenate will distribute the heavy sulphur-lime-arsenate of lead peach dust in a uniform and satisfactory manner if the agitation in the hopper is doubled and the rate of discharge of the dust reduced about one-half by cutting down on the outlet valve.

2. Around one thousand acres of peach orchards were commercially dusted in Georgia last summer from airplanes at the rate of about five thousand trees per hour. Under existing conditions of weather and infestation the fruit from orchards dusted by airplane was just as merchantable and of as good carrying quality as that from orchards dusted by ground machines.

3. The 0–5–95 peach dust should be used at the rate of about 1/6 pound per tree, and the 80–5–15 at the rate of about ¼ pound per tree. To get these dosages from an airplane the dust swath widths should be

[1]Hamilton, C. C. and Smith, C. M. A Colorimetric Method for Showing the Distribution and Quantity of Lead Arsenate upon Sprayed and Dusted Surfaces. Jour. Econ. Ent., Vol. 18, No. 3, June 1923, pp. 502–509.

[2]Messrs. C. H. Alden and H. S. Swingle of the Peach Insect Laboratory gave considerable assistance in taking the results of this work. Credit is due Mr. Alden for assistance in taking data on the drops and harvested fruit, and Mr. Swingle for conducting the colorimetric tests.

about 60 feet with the outlet valve ¾ open for the 0–5–95, and ½ open for the 80–5–15.

4. In order to make commercial airplane dusting of peach orchards more economical the capacity of the hopper in the ships should be increased, or a dust perfected which will give good results at smaller tree dosages than are now used. A convenient landing field should be located near the orchards to be dusted in order to reduce the mileage of the trips necessary to refill the hopper.

5. Results of cutting drops and harvested Hiley and Elberta peaches in two experimental orchards dusted by airplane and ground machine, respectively, showed that under conditions existing in Georgia last year airplane dusting was as effective as ground machine dusting in controlling the curculio in peach orchards.

6. Colorimetric tests showed that the airplane distributed lead arsenate in a dust mixture over the foliage of peach trees somewhat better than terrestrial machines.

7. Before the efficacy of airplane dusting of peach orchards can be definitely established further experimentation under varying conditions of weather and infestation will be necessary.

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CONTROL OF THE SNOWY TREE CRICKET IN PRUNE ORCHARDS

By CLAUDE WAKELAND, *Entomologist, Idaho Agricultural Experiment Station*[1]

ABSTRACT

Since 1910 the snowy tree cricket, *Oecanthus niveus* DeG., has been known to be injurious to prunes in the orchards of southwestern Idaho. For many years injury was restricted to one locality but damage became suddenly widespread in 1923. Primary injury is caused by the insects eating holes in ripening prunes which necessitates heavy sorting charges and forces many first quality prunes to be sent to the drier. Injured prunes cannot be entirely eliminated commercially and cause heavy loss in transit due to mold entering the fruits thru the broken skins. The snowy tree cricket feeds on leaves before attacking the fruit and experiments show that it can be effectively and economically controlled with arsenical sprays or dusts before it causes injury to the prunes.

HISTORY

Reports believed to be reliable indicate that the snowy tree cricket, *Oecanthus niveus* DeG., was damaging prunes in southwestern Idaho as early as 1910 and the insect is mentioned specifically as injurious to this crop in 1914 in the notes of T. H. Parks, who at that time was Extension Entomologist for the University of Idaho. One of the largest orchardists in that area, a college-trained man of investigational nature was the first to detect the injury and associate it with the insects he found to be numerous in his orchard. He kept careful record of the damage caused during the years 1912–24 and over the twelve-year period he estimated his annual loss averaged 10% per year and that during certain seasons it was as great as 25%. During this period the insect was known to be generally distributed in prune orchards in southwestern Idaho but in orchards, other than the one mentioned, it appeared to be of little economic importance. This condition changed when, in 1923, the insect suddenly became the pest of first rank in many prune orchards in southeastern Oregon and southwestern Idaho. Inspection reports of the Bureau of Plant Industry, State Department of Agriculture show that during that year more than 90% of all damage to prunes was caused by this insect and that in certain orchards the actual loss of commercial fruit was as great as 35%.

Climatic conditions in southwestern Idaho are peculiarly favorable to the production of Italian prunes which are shipped fresh and which are purchased in our eastern and middle western markets under the name of

[1]Acknowledgment is made of the aid given by the Bureau of Plant Industry, State Department of Agriculture; by Mr. F. E. Whitehead, Extension Entomologist for the University of Idaho; and by numerous orchardists.

"plums" or "purple plums." Due to conditions under which they are raised prunes from Idaho, eastern Oregon and eastern Washington are known to the trade to stand up in shipment better than those from many of the other prune-growing districts of the west. Figures compiled by the Idaho Prune Grower's Association in 1922 are to the effect that three-fourths of all the prunes shipped fresh in the United States are grown in a district comprised of southeastern Oregon and southwestern Idaho.

Nature of Injury

Direct injury to prunes is caused by nymphs and adults eating small holes into the fruit. When a puncture is made the insects commonly enlarge the feeding area inside the fruit while the skin puncture often remains small. It apparently is difficult for tree crickets to puncture the skin and they return to an injured spot and enlarge it from day to day. An injured prune ripens quickly, the skin becomes soft and large portions of fruits in this condition are frequently devoured. Counts of prunes at picking time are not truly indicative of the percentage of injury since those damaged early ripen prematurely and drop before the crop is harvested. In 1923 and 1924 it was common to find not more than 15% of the prunes injured at picking time while in the same orchards 33% of the fruit had been ascertained by the writer to be cricket-bitten when examined a month earlier. Direct loss comprises prunes that are devoured, those that drop before picking time and that are sorted out and thrown into the culls. Culls are either thrown away or from them the best fruit is resorted and sent to the drier. In either case the grower receives a decreased price for his product.

Indirect loss caused by the snowy tree cricket is greater than the direct loss and a source of more trouble and annoyance to the grower. If the extent of injury is very great the cost of sorting is exhorbitant and rather than try to grade the prunes so they may be shipped fresh the entire crop is often taken to the drier. Frequently when prunes are to be dried they are shaken on sheets rather than picked. When cricket-injured prunes are shaken, the soft, prematurely-ripened fruits are mashed and the prunes often reach the drier in a sticky, disgusting mess from which the sound fruits have to be sorted. To avoid this, growers are forced to pick the fruit and the cost of harvesting is thus materially increased. Chargeable to indirect loss, also is the expense of sorting prunes that are shipped fresh.

Transportation Losses

Probably the greatest indirect loss is caused by injured prunes that are not removed by the packing crew and which are packed in crates

destined for distant markets. The inspection laws of the state permit a tolerance of 5% which is considered adequate for the protection of the buyer and sufficiently elastic that the grower may grade his product to conform to the requirements of law without undue hardship. In a heavily infested orchard it is impossible, under practical conditions, to sort prunes close enough that the packed crates will not contain more defective prunes than the law allows. Many punctures are so tiny as to escape the eyes of the sorters and yet are large enough to admit disease organisms. On September 20, 1924, two crates of prunes selected at random from a pile that were lidded and ready to be put in a refrigerator car, were placed in cold storage where they were kept at a temperature of 43 degrees Fahrenheit for eighteen days. At the end of that time the writer ascertained that of the 662 prunes in the crates 13.35% were cricket injured; 7.08% of them had been bitten but the punctures had healed; 6.27% of them were developing mold; and 3.20% were so soft that they were partially or entirely broken down. Since packing, the approximate time had elapsed that prunes are often in refrigerator cars when in transit to distant markets. This incident offers an explanation of why growers often are forced to accept a reduced price or a loss on prunes that they believed to be of good quality but which are received on the market in a damaged condition.

Phases of Life History Influencing Control Methods

Life history studies and orchard observations of the Idaho Agricultural Experiment Station indicate that most of the nymphs emerge during late May and early June, a few eggs, however, hatch as late as the middle of July. Feeding injury can rarely be observed on prune leaves before July 15 but after that date it increases very rapidly and as many as 50% of the leaves of individual trees have been observed to have been fed on by August 8. Crickets remain in concealment on the undersides of the leaves during the day and are difficult to observe, thus orchards are often heavily infested when the owners of them do not suspect it. Feeding takes place, for the most part, from just before sundown until 10 P. M., during warm nights of summer and early fall and is resumed in the morning from a time shortly after daylight until sunlight strikes the foliage. Crickets eat the upper surfaces of the leaves almost entirely, rarely penetrating thru the lower epidermis. A small hole is first made, the margin of this hole then fed on and the area is enlarged until in extreme cases it may comprise as much as one-third the upper surface of the leaf.

Feeding on leaves continues until from July 25 to August 10. During

that time nearly all of the prunes are green, hard and sour but a small percentage, from various causes, begin to ripen prematurely. These are immediately attacked by the crickets, a few of which have reached the adult stage, and feeding thruout the remainder of the fall is confined chiefly to the fruit. When sound prunes begin to ripen normally, in late August and early September they are attacked and it is then that severe damage is done. As the area of the leaf surface eaten is great in proportion to the amount of food consumed and as the insects feed for days on the leaves before attacking the fruit, killing them by poisoning before they had opportunity to injure the fruit appeared practical and experiments were conducted by the writer to determine effective control measures.

Control Experiments

In laboratory tests in 1923, 100% of all crickets that fed on prune foliage which had been dusted with calcium arsenate or sprayed with lead arsenate, died in a period of time varying from 3 to 10 days after poison applications, and during a corresponding length of time from 25% to 51.25% died in the check cages. More time elapsed in obtaining a complete kill with lead arsenate spray than with calcium arsenate dust. On trees dusted with a hand duster and undiluted calcium arsenate the mortality of crickets was nearly one hundred per cent.

Two prune orchards known to be infested with the snowy tree cricket were used for experimental work in 1924. They comprised a total of 47 acres and were divided into plots sufficiently large to eliminate error caused by the "drift" of dust. Applications of poisons were made by a power orchard spray machine and a power crop duster. Dust was blown out in a continuous cloud thru a four-inch delivery tube. The team was driven at a steady pace and the plan of driving was such that dust was blown into the trees from both sides of each row. The following data were obtained by examining prunes at picking time in the various plots:

Tabulation of Results

	% fruit injured	
	Maximum	Average
Single application undiluted calcium arsenate dust	0.40	0.35
Double application undiluted calcium arsenate dust	0.50	0.33
Calcium arsenate 50%, hydrated lime 50%, dust mixture	0.45	0.38
Calcium arsenate 20%, hydrated lime 80%, dust mixture	1.05	0.53
Lead arsenate 8 pounds, water 200 gal	0.50	0.40
Lead arsenate 4 pounds, water 200 gal	1.20	0.92
Checks, foliage unsprayed or undusted	10.20	8.27

In addition to the above experiments others were conducted in which were used nicotine sulfate and sweetened baits. These proved to be impracticable or too costly and since results with them were not so good as with the materials mentioned, data will not be given here. Dust applications were made when atmospheric conditions were almost ideal yet there was a perceptible drift that extended as far as four rows distant from the one dusted. Undusted rows were left between dusted plots and it was found that due to the drift crickets were killed as effectively in these rows as in the plots. From this fact it was concluded that to dust each row from one side alone would give effective control and this method was later followed by commercial orchardists with entire success.

The degree of infestation and the extent of injury in the experimental plots were not so great as in many other orchards in the district. In one prune orchard it was determined that on August 8, 46% of the leaves had been fed on and that 14.74% of the prunes had been bitten at that early date. On August 10 this orchard, comprising 1008 trees, was dusted with pure calcium arsenate and during the next eight days 505 dead crickets were collected beneath one tree and 1386 beneath another. Dead crickets were very abundant beneath all trees in the orchard and the two count trees were selected at random. After dusting or spraying in any of the instances cited, numbers of trees could be shaken without dislodging a single live tree cricket and the scarcity of adults was further made evident when the chirping of males at night ceased entirely excepting in the check plots and in the foliage of high shade trees.

Oviposition

In southwestern Idaho, oviposition takes place from the latter part of August until the females succumb to low temperatures in late October and November. Parrot and Fulton[2] have well described the process. The thick, corky bark of the prune offers ideal material in which to oviposit and the difference in the thickness and texture of bark between prune and apple wood undoubtedly is an influence that accounts for the great numbers of the insects in prune orchards and their relative scarcity in apple trees. Even tho oviposition were common in apple wood it is not probable that the insect would become a pest of apple because of applications of arsenicals that are made for codling moth control. Oviposition is confined to the under sides of the larger branches almost entirely doubtless because the bark layer is so much thicker and more easily penetrated than on the smaller branches. Previous seasons' egg punctures become unsightly scars and it frequently is impossible to select an

[2]Bulletin No. 388, N. Y. Ag. Exp. Sta.

area an inch square on the undersides of the larger limbs which does not contain one or many egg punctures.

Cost of Control

Choice of the method of control under practical conditions depends on availability of machinery and on comparative costs, considering machinery, materials, labor and time consumed. The cost of dusting an orchard using a calcium arsenate undiluted, was found to be $2.58 per one hundred trees of which amount $2.39 was chargeable to cost of materials and 19c to man and horse labor. The cost of spraying with lead arsenate, 4 pounds per 200 gallons water was $4.58 per 100 trees of which amount $1.92 was chargeable to cost of materials and $2.66 to labor. From these data it is apparent that the cost of materials is about equal whether dusting or spraying is employed but that the cost of application by spraying is more than fourteen times that of dusting. During the time that is consumed in spraying 500 trees 4,000 trees can be dusted. If machinery is on hand and the acreage to be dusted is not large, spraying is the more economical but if acreage is extensive or new machinery has to be purchased dusting is much the cheaper.

Frequency of Control

Increase of the snowy tree cricket has been slow in the prune orchards of southwestern Idaho and it is probable that after an orchard has been thoroly dusted or sprayed it will not again become severely infested for a period of several years. Oviposition in the fall of 1924 was very heavy and normally the season of 1925 would have been one of heavy cricket damage. December 1924 was the coldest on record and the mortality of tree cricket eggs from the extreme temperatures was very high. Examinations of eggs, by the writer, in the bark during the spring of 1925 indicated that but 0.90% of them had survived. Due to this heavy winter mortality thruout the infested area there was almost no damage in 1925 and it is probable that several years will elapse before control will have to be practiced again.

Conclusions

The snowy tree cricket is the cause of severe loss to prune growers of southwestern Idaho.

It feeds on prune leaves for several days before attacking the fruit.

It can be effectively controlled by the application of 0.14 lb. undiluted calcium arsenate dust per tree or by spraying with lead arsenate at the rate of 4 pounds per 200 gallons water.

If poison applications are made after crickets begin feeding on leaves but before they attack the fruit they can be almost entirely eradicated in an orchard before they have caused any injury to the prunes.

Control by dusting can be obtained at a cost of 2.58c per tree.

Choice of control by dusting or by spraying depends on the cost and this is determined by availability of machinery and acreage to be treated.

Increase in the snowy tree cricket in prune orchards is so slow that control need not be practiced excepting at intervals of several years.

XANTHONIA DECEM-NOTATA SAY, AN APPLE PEST IN MAINE[1] (COLEOPTERA, CHRYSOMELIDAE)

By C. R. PHIPPS, *Maine Agricultural Experiment Station, Orono, Maine*

ABSTRACT

Xanthonia decem-notata Say, previously unrecorded in economic literature, has been very destructive to the apple in one district in Maine.

It has been recorded for a long time as an unimportant leaf feeder on the oak, beech, and elm. The beetle has a general distribution thruout the Eastern United States and Canada and has been taken as far west as Texas.

In the infested region in Maine the adult beetles migrate from other host plants to the apple in September and in the course of two or three weeks they may ruin the market value of the entire crop. The appearance of the fruit is spoiled by the abundant shallow feeding punctures scattered over the surface.

The trouble has been present in the same orchard for sixteen years and has gradually increased in severity. This season from 75 to 90% of the grower's Russet apple crop was injured.

The beetles, on the apple trees, were collected in tightly curled dry leaves during the day. Observations in the laboratory and orchard suggest that they are night feeders because they are characteristically hidden by day.

Two new host plants, besides the apple, are recorded as a result of feeding experiments. They are the wild raspberry, *Rubus strigosus*, and the linden, *Tilia americana*.

In the fall of 1924 a few small, brown leaf beetles were sent in to the Experiment Station for identification. They were collected in Winthrop, Maine in an apple orchard where they were reported as causing considerable damage to the fruit. The beetles were determined by Dr. E. A. Schwarz as *Xanthonia decem-notata* Say. Since this insect has previously been unrecorded as an economic insect the references which the writer was able to find consisted mainly of occurrence records in check lists. Nothing appears to be recorded regarding its life history and habits. Some of the records show that the beetle has been taken in New

[1]Papers from the Maine Agricultural Experiment Station: Entomology No. 119.

York, Pennsylvania, New Jersey, Florida, Indiana, Texas, Maine, and Canada. It therefore occurs rather generally thruout the Eastern United States and Canada and extends as far west as Texas. The fact that the insect has a wide distribution coupled with its potential possibilities as an apple pest suggested a report at this time.

The outbreak can hardly be termed sporadic inasmuch as the owner states that the trouble has been present in his orchard for the past sixteen years altho he had never seen the beetles themselves until last season. Moreover the problem has been one of grave commercial importance to the grower for a number of years and has gradually been increasing in severity. Since his crop this season was very clean when the writer visited the orchard a short time before the infestation began it can readily be seen that most of the cull fruit was caused by the agency of these beetles. At picking time, a few weeks later, practically 90% of the Russet apples had to be marked unclassified because of the work of these insects. The owner reported that, during previous years, the attack was more localized, three or four rows being especially favored. As other reports of late season injury to several varieties of apples have come to us since then from growers in the same district it is possible that future investigations may reveal a much more widespread attack on the apple than is now recognized.

The feeding punctures (Pl. 6, Fig. 1.) are shallow, somewhat resembling the work of late brood bud-moth caterpillars. This insect produces its injury later in the fall than the bud-moth and the feeding wounds are not accompanied by a webbing of the leaves over them as is so often the case where the bud-moth is concerned. Sometimes single punctures occur but more often there are several close together so that the margins overlap. The single punctures are usually circular in outline and about one sixteenth of an inch in diameter. They are seldom over an eighth of an inch in depth.

According to the accounts of this species which the writer has seen the host range is indicated as the leaves of oak, beech, and elm. It is so listed by Professor Blatchley from observations in Indiana. A brief survey of the territory in the immediate vicinity of the orchard in question was made early in October in order to ascertain, if possible, what the early season host plants were from which this insect later migrated to the apple. Some peculiar feeding punctures resembling the work of the closely related species, *Xanthonia villosula*, were noted on nearby oak and wild raspberry leaves. This observation led to some feeding experiments in the laboratory. Various sorts of leaves were offered the beetles in confinement and of these the wild raspberry, *Rubus*

strigosus, (Pl. 6, Fig. 2) and linden, *Tilia americana*, were accepted in addition to the previously recorded list of host plants.

An initial visit to the orchard in question was made on August 27, 1925. At that time none of the beetles were found in the orchard and there were apparently no injured apples. About the middle of September the owner informed the writer that the injury was beginning to appear in his orchard. By September 22, when another visit was made to Winthrop, from 75 to 90% of the Russets had been injured as well as some other varieties to a lesser degree. Great difficulty was experienced in locating the beetles in spite of the abundance of the freshly injured fruit. Finally, however, one beetle was located within a small, tightly curled dry leaf which was still attached to a twig. All the specimens collected were taken in similar retreats often quite far removed from any injured apples. Subsequent observations in the laboratory and in the orchard suggest that they are night feeders for they are characteristically hidden during the day, although they have been repeatedly seen feeding on the apples at night in the laboratory.

At picking time, October 14, no fresh feeding areas could be found on the apples and after a diligent search only one beetle was located. Evidently the feeding period on the apple is of short duration, probably not over two or three weeks this season. Since the adult beetles are recorded from April to October by Blatchley they must feed on the leaves or fruit of various other host plants until late in the season and then migrate to the apple.

The adult is described by Blatchley as follows: "Oblong or subquadrate. Brownish-red, sparsely clothed with suberect brownish pubescence; elytra each usually marked with 8 to 10 irregular piceous spots, sometimes wholly dull pale yellow; antennae and legs pale reddish-yellow. Head and thorax densely punctate. Front femur of male with a small tooth. Length 3 mm."

Nothing appears to be known about the larval stages but it seems probable that they are spent on the roots of some plant for the larvae of closely related species are root feeders.

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PLATE 6

Fig. 1.

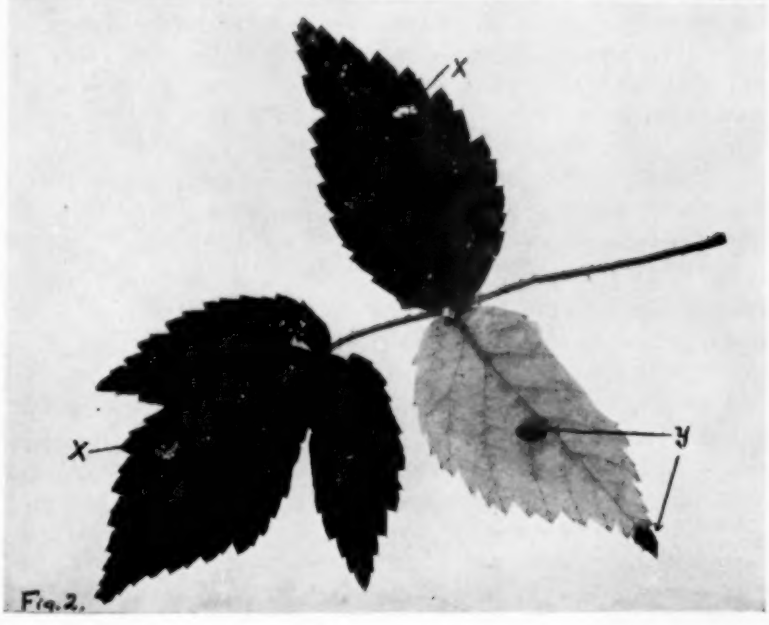

Fig. 2.

Work of *Xanthonia 10-notata:* 1, on Russet apple: 2 *X*, skeletonized areas on wild raspberry leaves; *Y*, Two beetles on under side of leaf.

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A NEW AND IMPORTANT SPECIES OF LEAFHOPPER INJURING APPLE IN OHIO

By D. M. DELONG, *Columbus, O.*

ABSTRACT

A new species of leafhopper, *Empoa malini*, has been found causing decided losses on apple in central Ohio. It has been the most abundant species on apple during the past two years. It closely resembles *E. rosae* with which it has apparently been confused. The color is more yellow than *E. rosae* but the easiest method of distinguishing them is by the terminal processes on the oedagus.

For the past two years leafhoppers have been affecting the apple in central Ohio in injurious numbers. The great majority of these insects reared from and collected on apple belong to a species which has apparently never been described. Although the biologic study has not been completed it seems best to publish a note regarding the economic importance of this species and its description. It closely resembles and belongs to the same genus as *Empoa rosae* (Linn) with which it has apparently been confused for a long time.

It is however, slightly smaller and more yellow or yellowish green than *E. rosae* which is usually white or pale yellow in color. From general field observations the life history is apparently similar to *rosae*. During the past season these insects have been so abundant in commercial orchards near Columbus that in addition to the feeding injury on the leaves fruit has been spotted by the secretion of a material similar to honey dew. This secretion on the fruit has caused a commercial loss due to a reduction in the market value of the apples. The problem is therefore an important economic one in this vicinity and an attempt is being made to gain as much knowledge as possible regarding the biology and control.

TECHNICAL DESCRIPTION

Empoa (Typhlocyba) malini n. sp.

Resembling *E. rosae* in form and general appearance, but slightly smaller, more yellowish in color and with distinct genitalia. Length 2.75–3 mm.

Vertex roundingly produced, a little more than half as long at middle as basal

width between eyes. Pronotum broader than head especially at humeral angles. Wing venation as in *E. rosae*.

Color. Somewhat variable, pale to bright yellow, often tinged with green. No dark markings.

Genitalia: Female last ventral segment rather long and produced to form a blunt angular apex. Male valve transverse, rounded at sides. Plates as long as valve and two preceding segments. Plates long, tapering to narrow attenuated tips which are upturned.

INTERNAL GENITALIA. The species can be separated from allied species only by the character of the internal structures. The tip of the oedagus in *E. rosae* bears four spine like processes which extend forward from a common origin. In *E. malini* there are five processes, two arise a little back of the terminus and extend upward (and slightly backward). The three at the tip arise at about the same point. The one arising dorsally extends forward and ventrally while the pair that arise ventrally

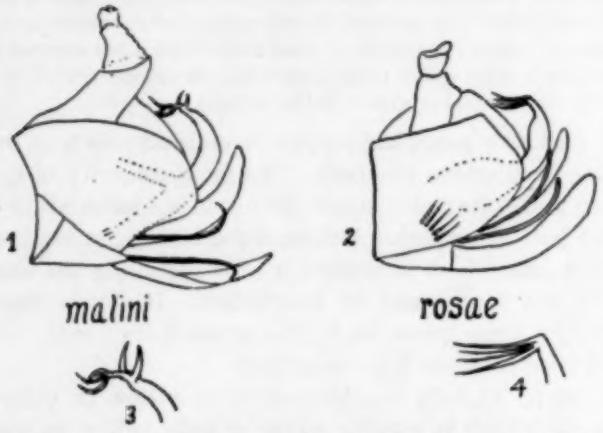

Fig. 23.—1, *Empoa malini*, n. sp., terminal portion of abdomen of male; 2, *Empoa rosae* (Linn) terminal portion of abdomen of male; 3, Tip of oedagus of *E. malini* (enlarged); 4, Tip of oedagus of *E. rosae* (enlarged).

extend forward and slightly dorsally. This is the best character for separation and is not really an internal structure as it can be seen as a rule if the elytra are lifted up. The genital chamber is usually open sufficiently to expose these structures. The styles are just dorsal to the plates and in the case of *E. malini* they curve outward very strongly at the apices. A large number of specimens of each species has been examined and these characters are apparently constant.

Described from a large series of specimens reared from apple at Columbus, Ohio, during July, August, and September, 1924 and 1925. Also a series of specimens collected during the summer of 1925 on apple by Prof. J. S. Houser, who has kindly sent me specimens for identification. The male is designated as the type. Type in author's collection.

SOME FACTS RELATIVE TO THE RASPBERRY CROWN BORER (*BEMBECIA MARGINATA*)[1]

By THOMAS J. HEADLEE, Ph. D., *Entomologist* and
CARL ILG, *Laboratory Assistant, New Jersey Agricultural Experiment Stations*

ABSTRACT

All larvae of *Bembecia marginata* pupate in latter part of summer. Work on both raspberry and blackberry seems to be of a crown-boring nature. Tobacco dust, properly used, destroys all larvae and leaves plants apparently unhurt. Margin of safety is much wider in tobacco dust treatments.

INTRODUCTION

Bembecia marginata, known frequently by the common name of *raspberry root borer* and *blackberry crown borer*, has been found in the course of this study to operate on raspberry far more like a crown borer than a root borer. In the territory lying in the vicinity of Hammonton and Egg Harbor there are several thousand acres of red raspberry. So far as our experience goes, it is difficult to find one cane that does not show the work of this insect. This injury has gone so far as greatly to reduce the summer crop and almost to eliminate the late summer and early fall crop. In fact, the senior author has never seen an infestation of this insect in any way equal to that which exists in the above mentioned district.

LIFE HISTORY

Previous investigators, such as John B. Smith[2] and W. H. Lawrence,[3] have indicated the insect as biennially brooded. Studies made during the present season show distinctly that all larvae in the raspberry stems pupate regardless of size. Pupation occurred from the middle of August to the middle of September. Emergence occurred from the end of August to the end of September. Eggs begin to appear (always on the undersides of the leaves) the first week in September, reached their maximum about the 20th and ceased to appear about the end of that month. Eggs began hatching about September 15th and by the middle of October the hatching had been completed. The newly hatched larvae were traced down the canes to a point just below the surface of the ground, reaching from one to three inches below the surface of the ground where each one proceeded to cut a shallow cell in the side wall of the canes. The larva erected a cover over this shallow cell, consisting of

[1]Paper No. 264 of the Journal Series, New Jersey Agricultural Experiment Stations, Department of Entomology.

[2]Smith, J. B., N. J. Exp. Sta. Spec. Bull. N, 1891.

[3]Lawrence, W. H., Wash. St. Exp. Sta. Bull. 63, 1904.

pieces of bark held together by silk. Within these blister-like chambers the larvae have grown and are, at the present time, December 15th, still resident.

Control

Previous investigators have indicated that the insect may be controlled by cutting out and burning infested raspberry bushes but, when this insect has reached the point where it infests most of the canes involved in the plantings, such a recommendation is, on the face of it, very impractical. It was, therefore, necessary to seek other means of destroying the insect. Para-dichlorobenzene had been tried by Dr. Peterson and he found that the lethal dosage for the insect was also the lethal dosage for the plant. There still remained the possibility of calcium cyanide, carbon bisulfide emulsion and, possibly, nicotine.

Calcium Cyanide

The calcium cyanide used was the granular product prepared by the American Cyanamid Company. It was sifted over the surface of the crown and the immediately surrounding soil. The soil was then mounded over the crown of the plants. The temperature at the time of treatment four inches below the soil surface was 80° F. The experiment was set July 24, 1925 and the data were taken July 30, 1925. Table 1 serves to set forth the results.

Table 1. Effect of Calcium Cyanide on the Advanced Larvae of *Bembecia marginata* and upon the Raspberry Plant

Block number	Calcium cyanide in oz.	Total larvae	Per cent killed	Condition of plant
1	1.0	6	100.00	Foliage dead
2	0.5	4	100.00	" "
3	0.25	7	100.00	" "
4	0.125	6	100.00	" seriously injured
5	0.0625	3	66.66	" " "
6	0.03125	3	00.00	" normal

From this table it is obvious that the lethal dosage of the advanced larvae is close to the lethal dosage of the plant.

Carbon Bisulfide Emulsion

The carbon bisulfide emulsion[4] consisted by volume of one part resin fish oil soap, three parts water and ten parts carbon bisulfide. The soap was first dissolved in the water and then the carbon bisulfide was poured into the mixture. The combination was shaken vigorously until a creamy emulsion was formed. The plants were prepared in two different

[4]Formula received from Japanese Beetle Laboratory.

ways for treatment. Each hill, representing blocks 1, 3, 5, 7, 9 and 11, was surrounded by a furrow two and one-half inches deep and a low dike pushed up on the outside of the furrow, enclosing an area about one square foot in diameter. Each hill, representing blocks 2, 4, 6, 8, 10 and 12, was surrounded by a low dike enclosing an area about one foot in diameter. To fourteen liquid ounces of the stock emulsion was added eighteen liquid ounces of water and the mixture thus made poured about the base of the hill, representing block 1, followed by thirty-two ounces of water. As soon as the liquid had largely disappeared from the soil the hill was mounded. The hill representing block 2 received precisely the same dosage. Thereafter the amount of material used was varied only in the amount of stock emulsion included. The total liquid treatment remained the same. The temperature four inches below the surface was 80° F. The applications were made on July 24, 1925 and the data were taken one week later. Table 2 will serve to show the result.

TABLE 2. EFFECT OF CARBON BISULFIDE UPON THE ADVANCED LARVAE OF *Bembecia marginata* AND UPON THE RASPBERRY PLANT

Block number	Amount of CS_2 in liq. ounces	Total insects	Per cent killed	Plant condition
1	10.0	6	100.0	Leaves dead & hanging
2A	10.0	5	100.0	" " " "
3	5.0	5	80.0	Edges of leaves burned
4A	5.0	5	100.0	" " " "
5	2.5	4	100.0	" " " "
6A	2.5	3	100.0	" " " "
7	0.93	7	28.5	Leaves normal
8A	0.93	3	100.0	" "
9	0.312	6	50.0	" "
10A	0.312	2	100.0	" "
11	0.156	5	60.0	" "
12A	0.156	3	66.6	" "

Note:—"A" indicates application to the surface.

The above table shows the superiority of surface treatments and that a lethal dosage for the advanced larvae occurs pretty well below the lethal dosage for the plant.

Studies of the effect of carbon bisulfide emulsion upon the pupae of *Bembecia marginata* show that they were not destroyed when nearly one-third of a liquid ounce of carbon bisulfide was used at a soil temperature four inches below the surface of 80° F.

Carbon bisulfide emulsion was tried against the young larvae of *Bembecia marginata*. All applications were of a surface character. Blocks 1, 2, 3, 4, 5, 6 and 7 received a total liquid treatment of two

quarts with a varying amount of the emulsion included. Blocks 8, 9, 10 and 11 received only 1 quart of liquid. The temperature four inches below the surface at the time of treatment was 71°F. Applications were made October 16th and 17th, 1925 and data taken about three weeks later. Table 3 serves to give the results.

TABLE 3. EFFECT OF CARBON BISULFIDE UPON THE YOUNG LARVAE OF *Bembecia marginata* AND UPON THE RASPBERRY PLANT

Block number	Amount of CS_2 in liq. ounces	Total larvae	Per cent killed	Plant condition
1	3.120	5	100.00	New shoots look brown
2	1.56	11	100.00	" " " "
3	1.248	14	100.00	" " " "
4	0.936	10	100.00	" " " "
5	0.624	12	100.00	" " less injured
6	0.312	20	100.00	" " " "
7	0.156	18	100.00	" " " "
8	3.120	16	100.00	" " look brown
9	1.56	19	100.00	" " " "
10	0.78	16	100.00	" " look hurt
11	0.312	10	100.00	" " " "

The above table shows that the weakest strength of carbon bisulfide used, which was 0.156 ounces, killed 100% of the larvae but that the same dosage turned the new shoots, which were just sprouting from the canes and, which in no cases exceeded one-half inch in length, brown. While it is possible that these new shoots might recover, it is undeniably true that they were injured.

NICOTINE

It was decided to employ tobacco dust as the source of nicotine in these trials. One pound of a 70–90 mesh tobacco dust analyzing 1.97 actual nicotine was employed in two blocks. The tobacco dust was sifted evenly over the crown of the hills and over the surface of the soil immediately adjacent, covering an area of about one foot in diameter. In block 1 the hill was promptly mounded with soil. In block 2 a low dike was pushed up around the hill, enclosing an area of about one foot in diameter. In this circular area was poured one gallon of water and, as soon as the water had largely disappeared from the soil, the plant was mounded. The temperature four inches below the surface at the time of treatment was 80°F. The applications were made July 24th and data taken one week later. Table 4 serves to give the results.

This table serves to show that tobacco dust applied in this way and in this amount kills a high percentage of the advanced larvae of *Bembecia*

TABLE 4. EFFECT OF TOBACCO DUST UPON ADVANCED LARVAE OF *Bembecia marginata* AND UPON THE RASPBERRY PLANT

Block No.	Amount of dust in lbs.	Mesh of dust	Nicotine content (lbs) of dust used	Amount (gals) water added	Total larvae	% killed	Condition of plants
1	1.0	70–90	0.0197		5	80.00	Normal
2	1.0	70–90	0.0197	1.0	3	100.00	Normal

marginata. It also serves to show that the application of water, following the tobacco dust treatment, increases the efficiency of the treatment.

Studies of the effect of tobacco dust, both wet and dry, upon the pupae of *Bembecia marginata* show that dosages of as much as one pound do not destroy the insect.

Studies of the destructive effect of tobacco dust placed about the base of the plants, when the eggs are present and before they have hatched, show that the descending larvae are not killed in sufficient numbers to render that treatment effective.

As soon as the larvae had all hatched from the eggs, gotten down on the plants, and formed the blisters, a further test of tobacco dust was made. In all cases two types of treatments were used. Surface treatment as set forth above: (1) sifting the tobacco dust over the crown of the plant and the soil immediately surrounding, followed by pushing up a low dike, application of one quart of water in the area thus formed, followed by the usual mounding; (2) sifting the tobacco dust over the crown of the plant and the soil immediately surrounding, followed by prompt mounding. In the table which follows the above types of treatments are indicated by the words wet and dry. At the time of application the temperature four inches below the surface of the soil was 71°F. The experiments were set up on October 16th and 17th, 1925 and the data were taken about two weeks later. Table 5 will serve to show the results. This table is arranged on the basis of nicotine strength and mesh fineness of the tobacco dust.

Certain interesting and important relationships are shown in this table, such as: (1) Relation of nicotine dosage to percentage of larvae killed; (2) relation of fineness of division and percentage of larvae killed; (3) relation of activator effect on evolution of nicotine to percentage of larvae killed. These points are brought out in figure 24.

It seems obvious, from these data, that: (1) the percentage of larvae killed varies as the nicotine dosage per hill; (2) the percentage of larvae killed varies as the fineness of division of tobacco dust employed; (3) the percentage of larvae killed varies as the evolution of nicotine gas; (4) addition of water to the tobacco dust treatment very greatly in-

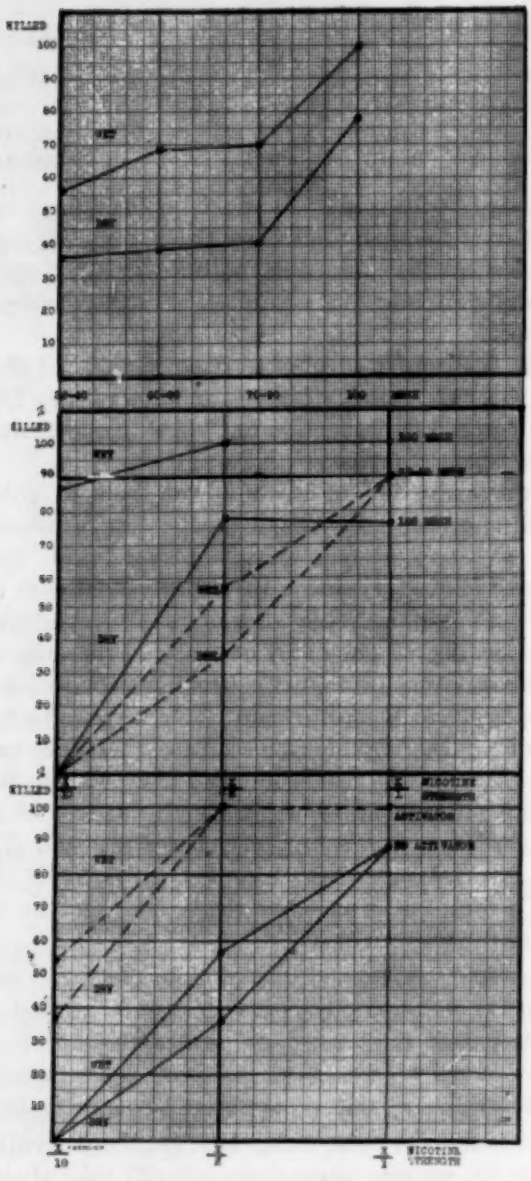

Fig. 24.—Graphic representation of relation of percentage of *Bembecia marginata* killed to: upper graph, fineness of tobacco dust used; middle graph, nicotine dosage; lower graph, tobacco dust treated with an agent (activator) for increasing the evolution of nicotine gas.

TABLE 5. EFFECT OF TOBACCO DUST ON YOUNG LARVAE OF *Bembecia marginata* APPLIED AFTER THEY HAVE SETTLED IN THEIR CELLS ON THE SIDES OF THE CANES

Block No.	Amt. of dust in lbs.	Mesh of dust	Nicotine content of dust applied in pounds	Total larvae in treatments		Percentage of larvae killed in treatments		Condition of plant		
				Wet	Dry	Wet	Dry			
1	1.0	100	0.0178	15	17	100.0	76.0	New shoots,		good
2	2.5	70–90	0.0195	15	11	80.0	81.8	"	"	"
3	1.8	60–80	0.0198	21	19	85.7	61.3	"	"	"
4	1.6	20–40	0.01968	23	18	89.3	88.8	"	"	"
5A[1]	2.0	100	0.0178	21	26	100.0	92.3	"	"	"
6A	3.6	60–80	0.0198	22	14	100.0	100.0	"	"	"
7A	3.2	20–40	0.01968	17	18	100.0	100.0	"	"	"
8	0.5	100	0.0089	14	22	100.0	77.2	"	"	"
9	1.25	70–90	0.00975	13	10	69.2	40.0	"	"	"
10	0.9	60–80	0.0099	16	13	68.7	38.4	"	"	"
11	0.8	20–40	0.00984	16	19	56.2	36.8	"	"	"
12A	2.5	70–90	0.00975	18	23	88.8	82.6	"	"	"
13A	1.0	100	0.0089	21	26	100.0	92.3	"	"	"
14A	1.8	60–80	0.0099	22	14	100.0	100.0	"	"	"
15A	1.6	20–40	0.00984	17	18	100.0	100.0	"	"	"
16	0.1	100	0.00178	25	23	88.0	00.0	"	"	"
17	0.55	70–90	0.00429	13	15	76.9	46.6	"	"	"
18	0.18	60–80	0.00198	12	14	58.3	35.7	"	"	"
19	0.16	20–40	0.001968	14	9	00.0	00.0	"	"	"
20A	0.5	70–90	0.00195	15	20	46.6	30.0	"	"	"
21A	0.2	100	0.00178	10	12	40.0	25.0	"	"	"
22A	0.36	60–80	0.00198	10	11	50.0	27.2	"	"	"
23A	0.8	20–40	0.00492	13	16	53.8	37.5	"	"	"

[1] "A" indicates the blocks in which the tobacco dust was combined with 49% hydrated lime and 1% sodium carbonate.

creases its efficiency; (5) tobacco dust treatments do not, even when used at large amounts, injure the raspberry plant.

It is believed that these data indicate nicotine gas as the agent destroying the larvae and that anything which contributes to its vigorous evolution, after the material is applied, will increase its efficiency.

In order to explain the use of the activator in these experiments, it should be said that Dr. Willem Rudolfs, in the course of some unpublished investigations relative to the evolution of nicotine from tobacco dust, has found that, by making a mixture composed of 50 parts of tobacco dust, 49 parts of hydrated lime, and 1 part of sodium carbonate, the evolution of nicotine gas from the tobacco dust can be so speeded up as to evolve several times as much nicotine in the same length of time as would escape without making the mixture. This speeding up occurs, however, only where the tobacco dust mixture is moistened.

THE 1925 OUTBREAK OF THE BEET LEAFHOPPER (*EUTETTIX TENELLA* BAKER) IN CALIFORNIA

By HENRY H. P. SEVERIN, Ph. D., and EDWARD A. SCHWING, B. S.

ABSTRACT

The spring dispersal of the beet leafhoppers (*Eutettix tenella* Baker) in the San Joaquin and Salinas Valleys during 1925 was the earliest since records have been taken in California, but the migratory flights in the Sacramento Valley were earlier in 1921. A disastrous outbreak of curly leaf occurred and about one-third of the beet crop was either plowed under or was not worth harvesting in the Sacramento Valley, while in the interior regions of the Salinas Valley curly leaf wiped out all of the late plantings. The summer brood adults flew at least three miles from beet fields planted in March, April and May to beet fields planted in June in the Sacramento Valley. A partial second brood developed on the foothills in the Salinas Valley and flew into the fog belt causing serious injury to late planted beets.

I. INTRODUCTION

It has been estimated that enough sugar beets could be grown in the San Joaquin and Sacramento valleys to supply the sugar requirements of the United States, a fact worthy of reflection, if the importation of cane sugar were cut off from this country during another war. According to the U. S. Bureau of Soils, there are 20,612 square miles or 13,191,680 acres in the great interior valley of California,—a portion of this area, however, has never been cultivated owing to lack of water for irrigation. The limiting factor of the sugar beet industry in California, is a disease commonly known as curly leaf, curly-top or blight carried by the beet leafhopper.

II. CLOSING, DISMANTLING AND MOVING OF BEET SUGAR FACTORIES

The growing of sugar beets in the San Joaquin Valley has been abandoned by the farmers and sugar companies except in the northern island districts owing to curly leaf. After the 1919 outbreak of the disease, three beet sugar factories were closed, the mills at Corcoran and Visalia were dismantled and moved out of California. Beets grown in the territory of the Tracy sugar mill were so badly blighted during 1919, that the factory failed to operate. In 1924 and 1925, the Tracy plant operated again, receiving its supply of beets from the Sacramento Valley and island districts in the northern San Joaquin Valley. The Tracy sugar factory may not operate next year. The beet sugar mill at Manteca was idle during 1922, 1923 and 1925.

In other parts of California beet sugar mills have been closed or dismantled and moved out of the state owing to curly leaf. In the Sacramento Valley the factory at Hamilton City was idle from 1920 to 1924, and operated again during 1925 but was closed after one season's run.

The beet sugar mill at Alvarado did not operate after the 1925 outbreak of the disease. The territory in the vicinity of the Chino beet sugar mill has always suffered severely from blight and the factory has been idle for years. During 1925 the Chino plant was dismantled and moved to Minnesota.

In the fog belt where curly leaf is usually not a serious factor except in years when the leafhopper is at the maximum in numbers, the increase and spread of the beet nematode worm (*Heterodera schachtii* Schmidt) has caused a reduction in the yield of sugar beets to such an extent that beet growing has become unprofitable in many localities. The competition of other crops, such as vegetable growing, is reducing the acreage of sugar beets in the fog belt, forcing the sugar companies to obtain acreage in the inland districts where blight is more prevalent. The future outlook of the beet industry in California is not promising, unless a practical solution of the beet leafhopper and curly leaf problem is found.

III. San Joaquin Valley

Spring Flights.—The dispersal of the beet leafhopper from the plains and foothills into the cultivated areas of the San Joaquin Valley was unusually early during 1925, the first records were obtained on March 29 and April 18, in the middle and northern parts of the valley respectively. In the 1919 outbreak of the pest, the first large flights occurred on April 14 and 28, in the same parts of the valley.

The spring flights of the beet leafhoppers from the plains and foothills into the cultivated areas of the San Joaquin Valley extended over a period of from four to six weeks in previous years. In 1925 no nymphs were taken on the pasture vegetation which was mostly dry on the plains and foothills on May 3. The flights extended over a period of about five weeks in the middle San Joaquin Valley.

An interesting observation was made toward the end of May when the adults were again found on Red Stem Filaree (*Erodium cicutarium*), the most important food and breeding plant on the plains and foothills. After the pasture vegetation became dry, the beet leafhoppers were found in large numbers on Russian Thistle (*Salsola kali tenuifolia*) and saltbushes. Heavy rains fell on May 12 and 13, and the old Red Stem Filaree plants became green again, and some of the seeds of Filaree had germinated. The spring brood males and females had left the Russian Thistle growing on the plains and at the base of the foothills and were taken on Red Stem Filaree on May 25 and 26. An occasional second brood nymph was also taken on Filaree. A trip was now taken to Little Panoche Valley where no Russian Thistle occurs on the floor of the

valley and on the hillsides. No nymphs or females were collected on Filaree although an occasional male was captured. Most of the males do not fly into the cultivated regions, but remain on the plains and foothills and die after mating. There was no evidence to show that a return flight from the cultivated districts to the plains and foothills had taken place where no Russian Thistle occurred.

IV. Sacramento Valley

Spring Migrations.—The first record of the spring migrants in the inland beet fields of the Sacramento Valley was obtained on April 29. The leafhoppers were very scarce in the island or delta beet fields of the valley on May 2. A large flight of the pest occurred on May 13, with variable winds from the south, southwest and southeast blowing on May 11 to 13. Mr. E. A. Schwing experienced what he considered a flight of the spring migrants into the beet fields at the Spreckels Ranch 33, near the city of Sacramento. The leafhoppers were flying everywhere and were settling on beets at dusk about 7 P. M. on May 13. In 1921, however, an earlier migration of the beet leafhoppers occurred than in 1925, a few adults were taken in the beet fields at Woodland on April 15, but no specimens were found in the Meridian beet fields, about thirty miles north of Woodland on April 16 and 30.

Flights Across Suisun and San Pablo Bays.—If the beet leafhoppers migrate northward from the San Joaquin Valley, it is evident that the adults flew across Suisun Bay to the beet fields at Suisun and Napa. The insects were also present in the sugar beet fields at Ignacio, crossing San Pablo Bay in their spring migratory flights.

Winds from Suisun Bay.—It was believed by sugar company officials that the winds from Suisun Bay which blow across the Sacramento Valley toward the Sierra Nevada Mountains, blew the beet leafhoppers away from the island or delta regions toward the inland districts. According to Mr. N. R. Taylor, U.S. Weather Bureau at Sacramento, the winds from Suisun Bay increase in velocity from 4 P. M. to midnight, decrease after midnight and are of least velocity during the early morning hours. Calm days are rare in the Suisun Bay regions during April and May, the months in which the migrations of the beet leafhopper occur in the Sacramento Valley. If the leafhopper migrates northward from the San Joaquin to the Sacramento Valley, the relation of the direction of the wind in the San Joaquin Valley to calm days in the vicinity of Suisun Bay probably plays an important role. Variable winds occur in the San Joaquin Valley such as northeast, south or west when it is calm in the Suisun Bay. South winds, however, do not blow

often in the San Joaquin Valley during April and May. Before the enormous hordes of bugs migrated into the Sacramento Valley during the spring of 1925, the senior author submitted a report to various sugar company officials in which he stated, "I see no reasons, with the information at hand from the Weather Bureau office, why it is not possible for the leafhoppers to invade the island or delta districts in large numbers during the spring flights if conditions are favorable in certain years."

YIELD.—In the inland districts of the Sacramento Valley, beet growing was gradually abandoned owing to curly leaf, by the Alameda Sugar Company and a new territory was developed in the island or delta country. A comparison of the average tons per acre in the inland, and island or delta regions, from 1919 to 1924 is shown in Table 1. The average tons per acre in the inland areas would be lower if the acres abandoned owing to curly leaf were taken into consideration.

TABLE 1. COMPARISON OF AVERAGE TONS PER ACRE IN THE INLAND AND ISLAND OR DELTA DISTRICTS OF SACRAMENTO VALLEY

	Inland		Island or Delta	
Year	Acres harvested	Average tons per acre	Acres harvested	Average tons per acre
1919	5780.5	5.7	60	9.6
1920	6840	5.6	1076	13.6
1921	3725	5.3	2847	7.4
1922	78	7.3	634	14.6
1923		—	4325	13.3
1924		[1]5.6	10683	13.5
				—
				[1]12.6

[1]Average obtained by dividing total tons harvested, by acres harvested.

It is evident from the above figures that in 1921 curly leaf caused a reduction of 5.5 tons in the island or delta country when compared with the average tons per acre of the other five years.

In 1925 about 40,000 acres of beets were grown by farmers and sugar companies in the Sacramento Valley, and about one-third of the crop was either plowed under owing to curly leaf or was not worth harvesting. Beets planted early made a marketable crop. The maximum yield of January plantings in one of the inland districts was 18 tons per acre, the average per acre was 13.2 tons. No beets were planted in February owing to heavy rains, the soil being too wet to plant. The average tons per acre of March plantings in the same inland district varied from 3.89 to 7.8 tons. April plantings were a failure. Beets planted in May were also a failure except such plantings as were made after the flights of the beet leafhoppers ceased to invade the beet fields.

Beets planted late in May after the flights ceased produced a marketable crop. No marked increase of the spring migrants occurred in the beet fields after May 22. Beets planted between May 23 and June 1, in a 220 acre field yielded an average of 8.5 tons per acre while 80 acres of this same field average 13 tons per acre.

Flights of Summer Brood Adults.—In many fields of unthinned and thinned beets examined in June a low percentage of curly leaf was present, owing to the fact that these beets had germinated after the flights of the spring migrants had ceased. The summer brood nymphs began to acquire the winged stage on July 1, and a gradual increase in the number of leafhoppers occurred in the late May, June and July plantings. An attempt was made to determine the longest distance that the summer brood adults flew into the late planted beet fields. One field of 100 acres of unthinned beets contained at least one beet leafhopper to each beet on July 14, and was isolated from other beet fields on all sides at the following distances: north 20 miles; east 15 miles; south 20 miles; west 3 miles. The summer brood adults flew at least three miles from the nearest beet fields to the 100 acres of unthinned beets. The flights may have been influenced by the prevailing winds from Suisun Bay. Some of the leafhoppers probably invaded the late planted beet fields from weeds growing in the vicinity. The question arises as to why the flights of the summer brood bugs occur from one beet field to another field. An examination of the beet fields planted in March, April and May showed that many of the beets had died owing to curly leaf. The terrific hot spells had scorched the outer leaves of the beets leaving a tuft of diseased, thick leathery leaves. In all probability the flights of the summer brood insects was associated with a food stimulus. During the 1919 outbreak of the pest, in the San Joaquin Valley the beets were mostly dead in July owing to curly leaf but instead of a dissemination to favorable host plants such as saltbushes, summer migrations occurred as reported in a previous paper (2).

V. Salinas Valley

Earliest Spring Flights on Record.—During 1925 the spring flights of the beet leafhopper occurred about seventeen days earlier in the Salinas Valley than during any year since records have been taken in California. In previous years the earliest flights occurred on April 10–14, 1914, and on April 10–15, 1916. The leafhoppers were found by Mr. W. Suttie in the beet fields in the interior regions and fog belt of the Salinas Valley on March 24–26, 1925. A second large flight occurred

over the Salinas Valley and the insects were also found in the San Felipe and Watsonville beet fields on April 12–14.

STIMULUS OF EARLY DISPERSAL.—The early development of the spring brood beet leafhoppers was associated with a warm dry winter. The stimulus of the early dispersal of the leafhopper from the foothills was probably due to the drying of the pasture vegetation. The monthly rainfall records at King City were as follows: October .36; November .32; December 1.23; January .38; February .95; March .94; April .93 and May 1.25 inches, a total of 6.36 inches for the season. The pasture vegetation became dry in January except on the north slopes. The root system of Red Stem Filaree, however, was not destroyed owing to drought and this plant became green again with the February rains. A dry period occurred from February 22 to March 26, with a limited amount of rainfall as follows: March 9 and 10, .11 inches. The early flights in the Salinas Valley on March 24 to 26 were probably associated with the second drying of the pasture vegetation.

PARTIAL SECOND BROOD DEVELOPS ON FOOTHILLS.—Late spring rains fell during March, April and May in the Salinas Valley and the pasture vegetation which normally becomes dry during April or May remained green until June. A partial second brood developed on the foothills and the hoppers were still present on the hills in June. The second brood invaded the late planted beet fields in the fog belt and caused serious curly leaf injury. A partial second brood usually develops on the plains and foothills of the San Joaquin Valley during the spring except in years when the pasture vegetation becomes dry in March as was the case in 1923.

During the 1925 outbreak of the pest large numbers of nymphs and adults were found during the summer on the perennial Australian Saltbush (*Atriplex semibaccata*) growing on the hillsides bounding the Salinas Valley near Metz. It was previously reported in the literature (1) that wherever annual saltbushes grow in the mountain passes along roadsides, or covering alkali sinks, the leafhoppers were taken which congregated on these plants after the pasture vegetation became dry on the foothills. It is evident that the foothills are not entirely free from beet leaf-hoppers after the pasture vegetation becomes dry.

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RESULTS OF LIFE HISTORY STUDIES OF *DIABROTICA 12-PUNCTATA* FABR. (CHRYSOMELIDAE, COLEOPTERA)

By HARVEY L. SWEETMAN, *University of Minnesota*[1]

ABSTRACT

The life history of *Diabrotica 12-punctata* as found under Iowa conditions is herein given. The beetles appeared in early June and began oviposition immediately. The greater portion of egg-laying ended in July. About 40 days were spent in the immature stages. Most of the adults emerged in July and August, but reproduction was apparently delayed until the following year.

The 12-spotted cucumber beetle is a serious pest of corn, cucurbits, and a great variety of other garden and farm crops. Walsh in 1866 first reported its depredations, stating that it was very injurious to flowers, especially dahlias, and inferred that it was responsible for injury to leaves of cucurbits. In 1870 Riley wrote that the insect could often be found imbedded in the rinds of melons, cucumbers, and squashes; in 1883 he found the larvae feeding on the roots of corn (Garman, 1891). The editors of insect life (1887) record its breeding on melons.

In Iowa the insect is not an important pest, by itself, of corn or cucurbits, but it adds materially to the destruction of cucurbits by the striped cucumber beetle, *D. vittata*.

METHOD

Adults were collected from cucurbit plants and pairs were placed in 72x24 mm. shell vials covered with nainsook cloth held in place by rubber bands. Daily the eggs were counted, removed, and put in moist soil. On hatching, each individual larva was dropped into a vial for rearing and at maturity allowed to pupate in the enclosed earth. Food consisted of portions of cucurbit stems and leaves for the adults and stems for the larvae.

This year, 1924, vine crops were backward in their growth because of the cold, rainy weather in the early spring and summer. In the vicinity of Ames, melons were a failure, cucumbers yielded poorly, and squashes and pumpkins were late in development. The climatic conditions and poor plant growth undoubtedly affected insect activities. Throughout the season field observations were carried on in conjunction with the insectary studies.

LIFE HISTORY

Daily trips for the collection of breeding stock began June 13 and continued until 17 females were caged, a period of 18 days. The beetles

[1]Some results of work at Iowa Experiment Station.

were very hard to find, and since they were common during the previous autumn, there must have occurred a high winter mortality. The first female was collected on June 17, three males having been gathered previously. This was about 10 days after cucurbits had broken through the ground. Sexes were usually found in close proximity as pairs, but no copulations were observed until fall and these were among the new generation in the insectary. Luginbill (1922) states that mating takes place in the fall and not in the spring, and Garman (1891) was unable to find developing ova in numerous females examined during the fall months.

Oviposition took place shortly after capture in the case of several females, indicating the probability of previous egg laying. The egg records for the season are given in Table 1.

TABLE 1. DAILY EGG LAYING RECORDS OF D. 12-PUNCTATA FEMALES

Cage No.	Date caught	Days lived	Total eggs laid	Eggs not laid	Cage No.	Date caught	Days lived	Total eggs laid	Eggs not laid
1	June 18	26	364		9	June 28	18	506	96
2	June 19	34	567		10	July 1	37	895	0
3–4	June 19	28	344	58	11	July 1	21	116	0
			345	59	12	July 2	16	342	0
5	June 20	15	239	125	13	July 2	11	381	114
6–7	June 24	27	281	0	14	July 3	15	295	0
			281	0	15	July 3	9	229	75
8	June 25	19	512		16	July 3	12	191	0
					17	July 6	12	233	11

Ave. No. eggs laid by one beetle	360
Min. No. eggs laid by one beetle	116
Max. No. eggs laid by one beetle	895
Ave. No. eggs not laid (found by dissection)	38.4

The highest number of eggs laid by one insect in 24 hours was 122. Most of the beetles died about the middle of July, showing that reproduction takes place early in the summer. There was one notable exception, a female found on August 19 that continued deposition until September 14. This appeared to be unusual as it was the only instance of late egg production on a large scale among 1,000 individuals collected in August. Under field conditions eggs are deposited in soil crevices about the roots of the host plant.

The eggs laid from June 18 to 20 failed to hatch because the environment provided was not suitable. The incubation periods from June 21 to September 14 are shown in Table 2.

As here indicated, extremes of 6 and 13 days were found with an average of 8.5. These variations were undoubtedly influenced by such

TABLE 2. INCUBATION PERIODS

Date of laying	Average incubation period	Date of laying	Average incubation period	Date of laying	Average incubation period
June 21	8	July 12	8.5	Aug. 16	8
June 22	13	July 13	8	Aug. 18	8
June 23	13	July 14	8	Aug. 19	7
June 24	10	July 15	8	Aug. 20	7
June 25	9	July 16	7.5	Aug. 21	6
June 26	12	July 22	8	Aug. 21	7
June 27	10	July 23	7	Aug. 22	7
June 28	10.5	July 24	7	Aug. 22	7.5
June 29	11.5	July 27	7	Aug. 23	7
July 2	8	July 30	6.5	Aug. 25	6
July 3	8	July 31	6.5	Aug. 26	7
July 4	7	Aug. 1	7	Aug. 27	8
July 5	7.5	Aug. 1	7	Aug. 27	10
July 6	7	Aug. 2	8	Aug. 28	9
July 7	7	Aug. 2	6.5	Aug. 29	10
July 8	7.5	Aug. 3	7	Sept. 1	13
July 9	7.5	Aug. 4	8	Sept. 4	12
July 10	7	Aug. 5	9.5	Sept. 7	12
July 11	7.5	Aug. 15	9	Sept. 13	13
				Sept. 14	13

Ave. 8.5 days. Min. 6 days. Max. 13 days.

environmental conditions as temperature and moisture. Eggs starting incubation on August 5, 15, 16, 18, and 19 were the last collected from stock cages containing several hundred beetles. After August 20 the eggs were produced by the female captured on August 19 as mentioned formerly.

The larval period is divided into the feeding and prepupal stages. Considerable difficulty was experienced in rearing through the latter stage and only a few cages were successful. Table 3 shows the records for 36 larvae, 6 being reared to maturity.

The average larva spent 3 weeks in feeding. Then it formed the pupal cell by pressing an opening double its size usually in the upper three inches of soil. The prepupal life required about 6 days and an additional 8 days were found to be necessary before transformation. The adult appeared a day or two later, making the average cycle from egg to imago about 38 days.

Three instars were passed through by the larvae. These were de-

TABLE 3. THE LARVAL AND PUPAL STAGES

Date larva emerged	Days in feeding period	Days in prepupal period	Days in pupal period	Days adult remained in cell	Total number of days	Date adult emerged
July 3	16	d				
July 4	15	d				
July 4	18	d				
July 4	18	d				
July 4	22	d				
July 5	18	d				
July 5	18	d				
July 5	19	d				
July 9	21	d				
July 11	19	5	5	1	30	Aug. 10
July 11	22	d				
July 18	23	d				
July 20	24	d				
July 22	16	6	9	2	33	Aug. 23
July 22	22	d				
July 22	22	d				
July 23	20	d				
Aug. 1	20	5	5	2	32	Sept. 9
Aug. 1	24	d				
Aug. 1	26	d				
Aug. 1	24	d				
Aug. 1	23	d				
Aug. 1	22	5	p			
Aug. 1	21	d				
Aug. 3	22	d				
Aug. 3	20	d				
Aug. 3	27	d				
Aug. 7	26	d				
Aug. 8	22	p				
Aug. 8	22	p				
Aug. 9	20	6	8	2	36	Sept. 13
Aug. 9	18	8	11	d		
Aug. 9	27	9	12	2	50	Sept. 27
Aug. 12	30	d				
Aug. 13	25	7	12	2	46	Sept. 27
Aug. 29	37	d				
Ave.	21.4	6.5				
Ave. (6)	21.1	6.3	8.5	1.8	37.8	
Min. (6)	16	5	5	1	30	
Max. (6)	27	9	12	3	50	

d—died
p—preserved

termined by the collection of cast skins and the following measurements of the head capsule:

Stage of development	Head length in mm.			Head width in mm.		
	Max.	Min.	Ave.	Max.	Min.	Ave.
First instar	0.25	0.20	0.223	0.19	0.18	0.183
Second instar	0.40	0.40	0.40	0.38	0.33	0.355
Third instar	0.60	0.53	0.556	0.50	0.49	0.493

Table 4 gives the periods spent in the various instars for 8 larvae. The first molt was not observed in the first cage, so averages of the first and second stadia were figured on a basis of 7, while the third was secured for only 2.

TABLE 4. INSTAR RECORDS

Date larva emerged	Stadia-days 1st	2nd	3rd Feeding	3rd Prepupal	Days pupal period	Days adult remained in cell	Total No. days	Date adult emerged
July 22		(9)	7	d				
July 22	6	5	5	6	9	2	33	Aug. 23
July 22	7	6	9	d				
July 22	6	7	7	d				
July 31	6	9	5	5	5	2	32	Sept. 8
July 31	5	12	7	d				
July 31	6	12	8	d				
July 31	4	10	10	d				
Min.	4	5	5	5	5	2	32	
Ave.	5.7	8	7.9	5.5	7	2	32.5	
Max.	7	12	10	6	9	2	33	

d—died

Upon emergence the adults immediately began feeding. In the field the over-wintering generation injured cucurbit seedlings very little in the spring of 1924 because only small numbers of the beetles were present. By midsummer these had increased to enormous numbers and did a great deal of damage to the foliage. Probably the dissemination of bacterial wilt, *Bacillus tracheiphilus* Erw. Sm. (Rand and Enlows, 1916, 1920), causes more destruction than actual feeding on the plants by the beetles.

While the adults attack only above ground portions of cucurbits, the larvae bore into the seedling stems and roots, sometimes causing wilting and dying which are often blamed on wilt and dry weather. In the southeastern part of the United States and along the Gulf of Mexico they are a very serious enemy of corn.

Only one generation of *D. 12-punctata* is produced each year. During the latter part of the summer and early fall the new generation was found

copulating. In the South the beetles do not enter a true hibernating state, but merely become inactive on cold days. It is generally supposed that in the North the adults over-winter, although no definite

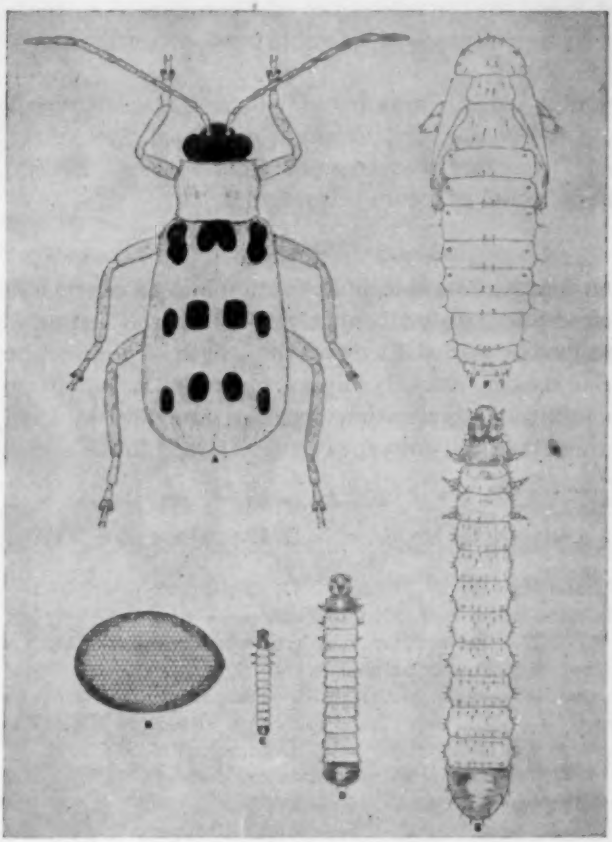

Fig. 25.—Stages in the life cycle of *Diabrotica 12-punctata: A*, Adult; *B*, Egg; *C*, *D* and *E*, First, Second and Third Larval Instars; *F*, Pupa(Original)

evidence to that effect is recorded. In this connection, while none of the few beetles reared in the insectary laid in the fall and the general lateness of copulation would tend to make one suspect that reproduction was delayed until the next season, yet it may be significant that occasional eggs were found late and in the case reported previously, one female laid steadily until September 14. Furthermore, one pupa raised in the

insectary was alive on December 2 though it did not survive the winter. Also enormous number of the beetles were present in the fall of 1923, but very few were to be found in the spring of 1924, as noted above. This at least suggests the possibility of other over-wintering stages. When frost killed the cucurbits, the adults migrated to the corn fields where they were present in considerable numbers until a heavy freeze on November 21.

No important parasite was found. During the fall months only, 3 specimens of a Tachinid fly, *Celatoria diabrotica* Shimer (1871), were reared from 7 maggots that emerged from beetles. Several hundred insects were collected to secure this number.

Summary

Seventeen females collected in the spring laid an average of 360 eggs which required 8.5 days for incubation. The larval instars were three, the average feeding period 21 days, the length of the prepupal life 6.3, the pupal 8.5, making a total of an average of 46.3 days to produce the generation. But one generation occurred annually in Iowa and the over-wintering stage has not yet been determined for this area.

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THE ECONOMIC IMPORTANCE OF THE CARROT WEEVIL IN ILLINOIS

By S. C. Chandler, *Illinois State Natural History Survey*

Abstract

A severe infestation of carrots by the Carrot Weevil, *Listronotus latiusculus* exists in an area in southern Illinois lying mostly within a 40 mile radius of E. St. Louis. A record of distribution is given, and studies of the life history and habits of the insect are reported with a note on its taxonomy.

Infestation

During the season of 1925 a serious infestation of carrots by the Carrot Weevil, *Listronotus latiusculus* was found in southwestern Illinois. From 50 to 70 per cent of the carrot patches examined during the late summer and fall contained infested carrots, and in most cases from 50 to 90 per cent of the carrots in the patch were injured.

This insect was first reported as injurious in Illinois during 1923, but statements of a number of carrot growers indicated that the injury must have been much the same for a number of years past. One grower stated that he had had considerable trouble for five years, another for eleven years, and still another for as much as sixteen years.

Distribution

Scouting to determine the distribution of the insect showed that serious infestation was mainly within a radius of 40 miles of E. St. Louis, outside of which only a few injured carrots were found. The accompanying map brings out this fact more clearly. On a scouting trip from Ashley, 60 miles from St. Louis, eastward to Mt. Carmel on the Indiana line, not one was found. Close to Mt. Carmel, however, one infested carrot was located. In the writer's garden at Carbondale, 100 miles southeast of E. St. Louis, three infested carrots were found in half a bushel, though none could be found in the gardens around. This concentration of the insect may possibly be explained by the distribution of its host plants. Within the infested area practically every family has a garden, and in most of the gardens carrots are grown. Parsley is grown by comparatively few. Outside of this area, in one section 90 per cent of the gardens did not contain carrots. Another explanation lies in the fact that there are a few more truckers near St. Louis than elsewhere. According to reports from Illinois growers in Monroe County, the same conditions occur on the Missouri side of the river. Of the other points indicated on the map, those at Springfield, and at Edgebrook (near Chicago) represent all our records antedating this year. Those at Rock Island, Mt. Carmel, and Carbondale are based on the characteristic injuries to the carrots.

Taxonomy and Literature

Very little has been written on this insect. The fullest account was published by Chittenden in 1909 in Bul. 82, Pt. 2, of the U. S. Bureau of Entomology. Dr. C. M. Weed reported in 1889, in Art. 2, Volume 1 of the Bulletin of the Ohio Agricultural Experiment Station,

the rearing of *L. latiusculus*—from common arrow-weed, *Sagitaria variabilis* and it has been supposed that the species is semi-aquatic. Doubt was expressed about this point by Chittenden in a paper read before the Brooklyn Entomological Society in 1924, suggesting that there might have been a mistake in the identification of the species

Fig. 26.—Distribution of carrot and parsley weevil, *L. latiusculus*.

reared by Weed. The original Weed specimen was determined by C. A. Hart in Illinois, and it is still in the collection of the State Natural History Survey. Dr. T. H. Frison, Systematic Entomologist of the Survey, has gone over all our material. Of the four specimens from

Illinois earlier than those received this year, he found two collected at lights by C. A. Hart in 1885 at Springfield on July 2 and 4 respectively., and one from Edgebrook, near Chicago, collected on June 16, 1917, this last specimen identified by Blatchley and given to the collection by Mr. C. A. Frost, of Framingham, Mass. The larvae which I took this year were reared at Urbana. The imagos were determined by Dr. Frison, and the determination was confirmed by Mr. C. A. Frost, as were those I found this winter in hibernation. Dr. Frison found that the specimen reared by Weed is much smaller than any others of *L. latiusculus* he has seen, and has a brighter color. He is not satisfied that it is the same species as that bred from carrots, and Mr. Frost to whom the specimen was sent is equally in doubt, although he could not separate it from *latiusculus* by any decided structural difference. In this connection it might be mentioned that the species which throve so well in carrots during the exceptionally dry season just past, appeared to be anything but aquatic.[1]

Life History and Habits

This species is apparently single brooded in Illinois. Larvae taken in carrots from Clinton County in the worst infested area produced adults the first week in August and emergence continued for two weeks. The larvae taken at Belleville, within the same area yielded adults on August 25. No copulation, or egg laying was observed in the cages. Although the records from our collection show that there are some adults abroad during June and July, my observations indicate that very few are to be found during July. I received some corroboration of this from a truck grower in Monroe County, who stated that his early sown carrots and parsley are always heavily infested, while his July sown crop is much less injured.

An effort was made to note any preference for either of the two principal host plants, carrots and parsley, but as so little parsley could be found not much information was secured. One observation, however, would indicate that carrots were preferred. On the above mentioned farm where carrots and parsley, planted at the same time were found growing side by side, only an occasional infested parsley plant was to be found, while the carrots were 60 per cent infested.

The injury is usually confined to the crown or upper part of the plant, but often extends well down through it. As many as 2 or 3 larvae often work in a single plant. Some growers of garden carrots com-

[1]Specimens of *L. rudipennis* Blatchley were reared during the past season from carrots taken in gardens in Clinton County, Illinois.

plain that even if the lower part of the carrot is uninjured, it is too woody to be good for table use.

Some hibernation studies were made in the vicinity of badly infested patches. Though by no means complete, they indicate that the principal hibernating quarters are not in the patch itself. Beside general examinations the likely kinds of cover were examined in the vicinity of several truck patches of carrots. For this work, a screened box was employed, and the material was sifted through onto an oil cloth. About 150 sq. ft. of the following kinds of cover were gone over:

Trash in carrot bed itself, grass, and crop refuse.
Ground underneath, down to 3 inches.
Tops of carrots still in the ground.
Refuse in garden, not in carrot patch itself.
Fence rows of the gardens, in trash and grass.
Currant and blackberry bushes along the edges of garden.
Bluegrass on south slopes nearby.
Bunch grass (Andropogon) on south slopes nearby.
Woods nearest to patches, south and west edges.

Thus far only three specimens have been found in hibernation, two in frozen carrot tops, and one under leaves in a garden but not in the carrot patch itself.

It is planned to continue these studies as time will permit. These records and observations are given here as a statement of our present knowledge of this insect, and in the hope that they may be of benefit to other investigtors.

A NEW CARROT PEST, WITH NOTES ON ITS LIFE HISTORY

By HALBERT M. HARRIS[1]

ABSTRACT

A weevil, *Listronotus rudipennis* Blatchley, apparently heretofore unrecorded as a pest has been found attacking carrots in Iowa. The injury is done by the larvae which tunnel and feed on the underground parts of the plants. In severe infestations as much as 90 per cent of the crop is rendered unfit for human consumption. The weevil requires about 31 days to complete its life cycle from egg to adult. Breeding is continuous throughout the summer.

During the past summer, 1925, complaints of a pest attacking carrots in what appeared to be a new and a serious way were received

[1]Contribution from the Department of Zoology and Entomology, Iowa State College, Ames, Iowa.

by the Entomologist of the Iowa Agricultural Experiment Station. Requests for specimens of the infested plants were immediately made. These plants upon arriving disclosed the fact that the injury was being done by larvae of a weevil, a species apparently heretofore unrecorded in literature as a carrot enemy. A trip to a small truck farm near Burlington, Iowa convinced the writer of the seriousness of the damage caused by the weevil. There it was found in the field in all of its stages. The carrots were an almost complete loss, fully 90 per cent being practically unfit for human consumption. Questioning revealed the fact that other growers had been troubled with the same pest, some of them for eight to twenty years, or as long as they had been trucking.

The weevil has been identified by Mr. W. S. Blatchley as *Listronotus rudipennis* Blatchley. In the adult stage it is black and densely clothed above with reddish-yellow scales having a more or less pronounced coppery tinge. It measures from 5.8 mm. to 6.3 mm. in length.

In the field the adults were common on the foliage of the carrots. When disturbed they fell to the ground and would lie motionless for a few moments before crawling away. Although they possess well developed wings and apparently are able to fly, no individual was ever observed to attempt to do so. Their food consisted of any part of the carrot plant.

The egg is elongate oval and about .73 mm. long. At the time of deposition it is a pale yellow in color, this color gradually changing to a deep fuscous during the incubation period. Those that did not hatch, probably due to infertility, did not seem to acquire this darker color. The female deposits her eggs in small cavities which she eats in the bases of the stems and in the crown of the plant. During oviposition her abdomen is extended into the cavity, and the eggs are apparently arranged by a slight shifting of the tip of the abdomen as they are laid. When through placing the eggs the genital segments are raised and a small amount of a sticky blackish substance is dropped over the cavity. This substance soon hardens and forms a cap which seals the egg-pocket.

The number of eggs per cavity varies with the individuality and fecundity of the females. The greatest number found in 225 pockets examined was eleven, the average being about 5. One female among those under observation had a record of 40 eggs laid within a twenty-four hour period. This individual from July 21 to August 19 inclusive

deposited a total of 546 eggs or an average of 18.2 per day.[2] Two other females during the same length of time had a daily average of only 5.5 each.

The eggs hatch in from 5 to 7 days. As the period of incubation draws to a close the position of the larva within the egg is readily discernible. At the end of this time the larva punctures or rips the egg membrane by means of its large mandibles. It then, by extending the body is able to tear the membrane sufficiently to escape, after which it begins to eat into the carrot. Here it remains until full grown, tunneling usually parallel to and near the surface. It grows rapidly and in about 21 days is ready to pupate. During the feeding period it undergoes three molts and increases in size enormously. The pupal period is spent in an earthen cell constructed by the larva usually within an inch or two of the place of emergence from the carrot. The larvae cease feeding about a day before entering the soil and remain in the pupal cells for an equal period before transforming into pupae. The pupal period varies from 4 to 10 days. After shedding the pupal skins the weevils remain within the cells for several hours.

The life cycle from egg to adult requires about 31 days. In the breeding cages the adults after emergence fed for a period of 10 to 12 days before the females began to oviposit. Records indicate that there are probably three generations with continuous breeding throughout the summer. Hibernation is apparently in the adult stage.

The insect listed as *L. latiusculus* Boh. by Chittenden (Bul. Brooklyn Ent. Soc., XIX, 1924, p. 84) apparently was *L. rudipennis* which would account for the aberration in habits as noted by that author.

THE CARROT CURCULIO, *Listronotus rudipennis* BLATCHLEY

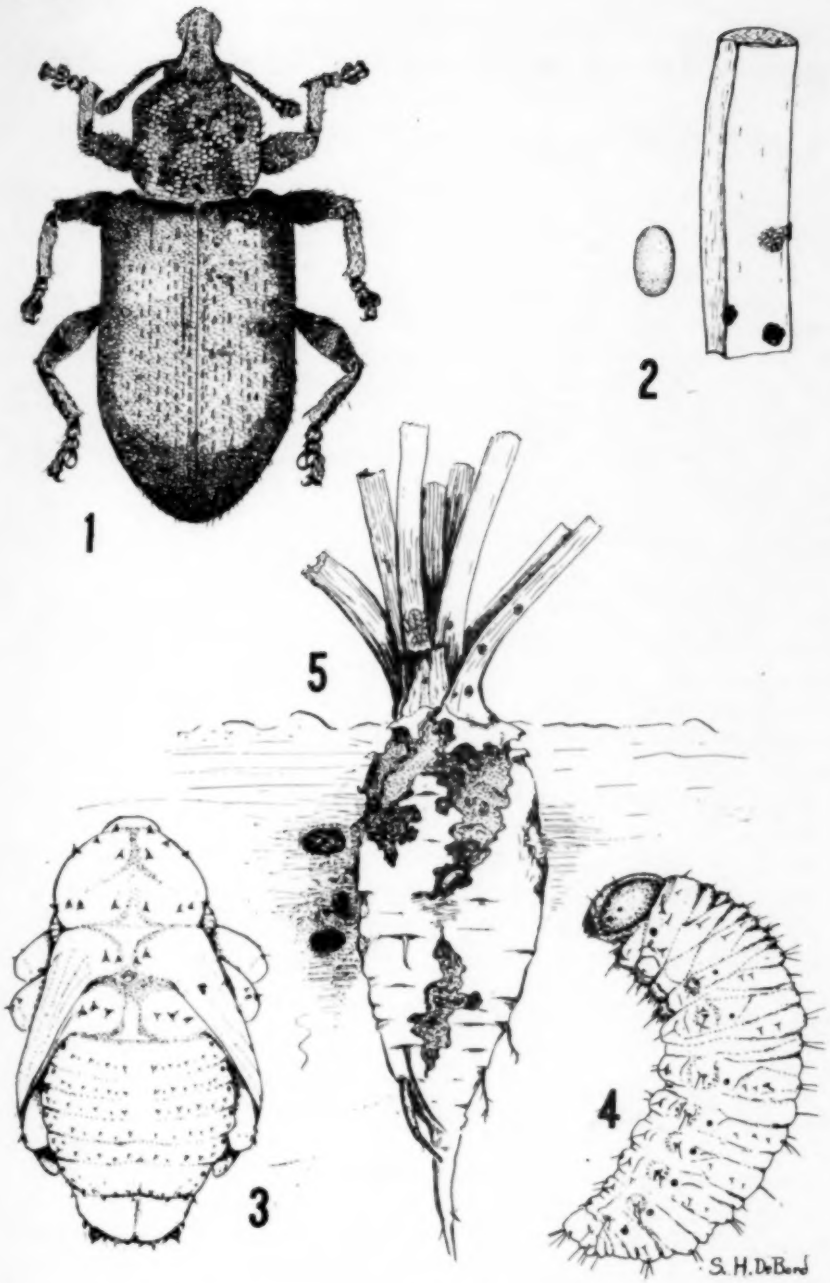
Length of Stages in Life Cycle

Stage	No. of individuals	Days required Maximum	Minimum	Average
Egg	20 lots*	7	5	6.1
1st larval instar	17	6	3	4.1
2nd larval instar	15	3	2	2.7
3rd larval instar	20	4	2	3.4
4th larval instar	17	14	7	9.2
Pupal	43	4	10	6.5
Egg to adult	30	34	25	30.9

*The word lot as here used includes all those eggs placed within one egg-pocket.

[2]The total given does not represent the number of eggs deposited during the life of this individual.

PLATE 7



Listronotus rudipennis Blatchley; 1. Adult weevil (x 10); 2. Egg (x 14). At right, stem of carrot showing nature of egg pocket and its cap; 3. Pupa (x 10); 4. Larva (x 10); 5. Infested carrot showing injury due to tunneling of larvae (adult weevil and egg pockets on stem, larva in tunnel, pupa and pupal cases on left).

OBSERVATIONS ON THE LIFE HISTORY OF THE NARCISSUS OR DAFFODIL FLY, *MERODON EQUESTRIS* FAB.

By C. A. WEIGEL, *U. S. Bureau of Entomology, Washington, D. C.*

ABSTRACT

The observations recorded in this paper indicate that the seasonal life cycle of the narcissus or daffodil fly (*Merodon equestris* Fab.) at Washington, D. C., is as follows: This species overwinters in the larval stage and pupation occurs during April. The higher temperatures of the greenhouse apparently hastened pupation since it took place during February, whereas outdoors it did not occur until April. Adults emerged from April 24 to June 4, and their longevity ranged from 4 to 17 days. Extracted honey proved to be a suitable food for the adults under cage conditions. Sunlight appeared to be a requisite for mating and egg deposition. Eggs were laid on the bulbs and hatched in from 2 to 9 days. Newly hatched larvae began feeding in the bulbs during May and June and were nearly full grown by November.

Ordinary earthen bulb pans, plunged in sand, in specially constructed boxes placed in a cold frame served as suitable life history cages. About 1,300 acres are now devoted to bulb production in the United States, and the states in which these commercial producing areas occur are named.

For many years it has been the custom to import from France and Holland the narcissus, tulip, and hyacinth bulbs that are used in this country, annually, for forcing in greenhouses for cut flowers, and for bedding stock. Almost every shipment of imported narcissus bulbs is found to be more or less infested with such bulb pests as the narcissus or daffodil fly (*Merodon equestris* Fab.), the lesser bulb fly (*Eumerus strigatus* Fallen), the bulb mite (*Rhizoglyphus hyacinthi* Boisd.), and the stem nematode (*Tylenchus dipsaci* Kühn). Because of the possible risk to our domestic bulb cultures and other agricultural crops of infestation resulting from the continued introduction of these pests in infested bulbs, announcement was made by the Federal Horticultural Board that narcissi would be excluded from further entry after January 1, 1926.

This proposed embargo aroused considerable interest in the production of narcissus bulbs, and, incidentally, has tended to stimulate planting on a commercial scale in order to produce a supply of forcing bulbs to replace those that would be excluded when the quarantine became effective.

The production of bulbs suitable for forcing is restricted to certain rather definite areas, although bulbs, in general, will grow in this country under a wide range of climatic conditions. The principal commercial bulb-producing areas in the United States occur in California, Oregon, and Washington, on the West Coast; Long Island, N. Y., New Jersey, Virginia, North and South Carolina, Georgia, and

Florida, on the Atlantic Coastal Plain; Mississippi, and Texas, on the Gulf Coast; and Illinois, Indiana, Michigan, and Tennessee.

In certain localities, however, there are also naturalized plantings in which bulbs have been growing for a long time. For example, in North Carolina the bulbs in one planting originated from stock that had been growing in this country for more than 150 years. A few of these naturalized plantings are devoted to flower production, especially in the Tidewater region of Virginia.

A recent survey made by the Department of Agriculture indicates that roughly 1,300 acres are planted to bulbs, and that there are now total plantings of about 150,000,000 bulbs in this country.

The tremendous expansion in the bulb industry, especially during the last three years, and the fact that some of the imported planting stock was infested with bulb pests, has increased the risk that these pests might become established in different sections of the country, and especially in the old, uninfested naturalized plantings.

As a result of the increased interest in bulb production, the Bureau of Entomology has naturally been called upon frequently for information regarding these imported bulb pests. In most cases such information has been available only in the form of a digest of the foreign literature on the subject. A review of the American literature revealed the fact that entomologists apparently had given little attention to these pests from the point of view of life history studies and control measures, and that most of the published accounts dealt with interception, collection, or distribution records.

During the past five years, however, some tests have been conducted by fumigating with various poison gases, particularly hydrocyanic-acid gas, and carbon disulphide, to determine their value in disinfecting infested bulbs.

The first definite attempt to study the life history of either of the bulb flies in this country from an economic angle appears to have been made with the lesser bulb fly during the fall of 1924. The results of these studies were presented at the Washington meetings last year.[1]

This paper presents a brief summary of the rearing method employed and notes on the seasonal development of the narcissus fly (*Merodon equestris* Fab.) under normal growing conditions at Washington, D. C. For this investigation narcissus bulbs infested with nearly full-grown larvae were obtained from the Pacific Coast in August, 1924. In order

[1]Broadbent, B. M. Notes on the life history of the lesser bulb fly, *Eumerus strigatus* Fallen. Journal of Economic Entomology. Vol. 18, No. 1, p. 141–143, February, 1925.

to insure favorable conditions for their development, these larvae were disturbed as little as possible. As a result only general notes could be taken, and no attempt was made to get exact, detailed observations on the development of the several stages.

To provide as nearly normal conditions as possible for rearing the larvae, a definite number of infested and of sound bulbs were planted in round earthen bulb-pans, 9 inches in diameter and 5 inches high. The pans were prepared by placing a piece of screening over the drainage hole to prevent any of the specimens from escaping through it. To insure proper drainage, a layer of small pieces of broken flower-pots and ashes was put in the pans, and then covered with a layer of soil 1½ inches deep. Eight infested bulbs were usually planted in the centre of each pan, and these were surrounded with a ring of thirteen sound, uninfested narcissi, so that if a larva crawled out of a bulb it could easily find suitable food in which to complete its development. After placing the bulbs on the soil, they were covered with another layer of soil 1½ inches deep, so that the pans were filled level full. By carefully cutting into each infested bulb it was possible to determine the presence of the larva without injuring it.

Pans of bulbs were planted on the following dates: September 25, October 3, 6, and 10, November 7, and December 6, 1924.

To guard against the possible escape of adults during emergence, the pans were placed in special cages constructed from wooden boxes 32 inches long, 12 inches wide, and 11 inches deep. The bottom of each box was first covered with 14-mesh wire screening over which wooden slats 2 inches wide were nailed to serve as a support for the pans placed therein. Three pans were then placed in each cage on a 3-inch layer of sand. Finally the remaining space, except the last two inches, was filled with sand. To complete the cage, the top was also screened. These cages containing the life history pans were then placed in an exposed cold frame in which a good ash drainage had been provided, and were left there over winter for further developments, except as noted below.

By February 20, 1925, some of the bulbs had started to sprout and, in order to permit better observations, sufficient sand was removed from each cage, so that the top surface of each pan was plainly visible. Sash was placed over one section of the cold frame temporarily in order to protect the newly exposed shoots from freezing. As soon as the shoots became hardened, however, the sash was removed so as to permit normal outdoor or field conditions to exist. By April 9, the foliage had become so dense that it was pushing against the wire screening and had to be cut back several inches to prevent its interfering with taking observations.

To get comparative data on the effect of greenhouse temperatures on their development, a pan of bulbs was brought in on November 20, 1924. Apparently the conditions were not satisfactory, for only one larva pupated, and by April 20, 1925, the remaining seven larvae had decayed. Another pan brought in on December 27 did not appear to behave normally either, because only two flies emerged and the other six larvae decayed. In the greenhouse, the first pupa was found on February 18, and the first fly emerged February 22. The pupal stage appeared to last approximately three to five weeks.

In the cold frame, however, development appeared to be normal and took place more slowly than under greenhouse conditions. For example, the first pupa was found seven weeks later, on April 9. The flies did not begin emerging until April 24, but they continued to emerge from this material until June 4. Seven flies emerged during April, thirty-six in May, and three in June.

With reference to larval habits, it was noted that the larva, when ready to pupate, works its way out of the nose of the bulb in which it has been burrowing or feeding, and migrates upward through the soil to the surface where it assumes a slanting position directly over the bulb, or its old burrow. The tip of its head is exposed, and its breathing spiracles are clearly discernible while in this position. This habit is interesting and significant in that it offers a weak point in the life cycle which can be taken advantage of in applying control measures. For example, the exposed pupae could be destroyed by mechanical means, such as cultivation, or by the application of some corrosive or suffocating agent.

In order to secure eggs for the next generation, the flies were removed from the cages as they emerged, and confined in breeding cages that contained pans of normal uninfested bulbs. It was found that these flies would feed on extracted honey smeared on the wire of their cages just as the lesser bulb flies had done. Mating occurred only in the sunlight, and was first noted on May 2. It was also observed after one o'clock on May 9, when the temperature was 75° F. in the shade, and 80° F. in the sun. Egg laying was first observed on May 8, and the final date was June 6. Eggs were found to be deposited on the bulbs among the thin brown outer bulb scales, on green foliage, or on dried leaves close to the bulb, and occasionally on the soil.

The longevity of the flies appeared to vary from 4 to 17 days, and averaged about 9 days. The incubation period for the eggs appeared to require from 2 to 9 days, the average being about 6 days. A newly hatched larva was observed to work its way down through one of the outer bulb scales to the basal plate through which it apparently bored

its way into the interior of the bulb, although this phase was not observed further.

Pans in which eggs had been deposited were removed from the breeding cages at frequent intervals, and on June 2 placed in cages in the cold frame where they were treated in the same way as the larvae of the previous generation. Pans of sound, uninfested bulbs were used to replace those removed from the breeding cages after oviposition had taken place. Although a few of the pans in the cold frame were examined at monthly intervals, the majority were left undisturbed to permit a normal infestation to develop. The bulbs in one pan, examined on July 2, were 66 per cent infested, and another lot examined on September 28 proved to be 75 per cent infested. In the latter case the larvae within these bulbs appeared to be nearly full grown at that time.

From these observations the seasonal life cycle of the narcissus fly appears to be as follows: Under normal, or outdoor conditions, this species overwinters in the larval stage and pupation occurs during April and May. Pupation is apparently hastened by high temperatures because it took place in the greenhouse during February and did not occur outdoors until April. The adults emerged from April 24 to June 4, and their longevity ranged from 4 to 17 days. Extracted honey proved to be a suitable food for the adults under cage conditions. Sunlight appeared to be a requisite for mating and egg deposition. The incubation period for the eggs ranged from 2 to 9 days. Newly hatched larvae which began feeding in the bulbs during May and June reached considerable size by early August, and were full grown by November. At that time they appeared to be rather sluggish, and probably did not feed much during the winter.

These observations indicate that the seasonal development of the narcissus fly in this part of the country is in substantial agreement with its development in Holland and England. It also indicates that this species is capable of living continuously from year to year in case it should become permanently established in some of our domestic bulb cultures in the eastern part of the United States.

ERRATA

The insidious plant bug designated as *Phloeothrips* in Journ. Econ. Ent., 19:170, 1926, should have been *Triphleps*, there having been an inexplicable substitution in the genus name.

OBSERVATIONS ON THE BIOLOGY OF *MELANOTUS COMMUNIS* AND *MELANOTUS PILOSUS*

By F. A. FENTON, *Florence, S. C.*

ABSTRACT

Two of the most common wet land wireworms in Iowa are *Melanotus communis* Gyll. and *M. pilosus* Blatch. They have a six year life cycle, the adults laying eggs chiefly in June of the first year, the larvae hatching mostly by July. The second, third, fourth and fifth years are spent in the larval stage. Pupation takes place usually in August of the sixth year and the adults emerge on an average of from 14 to 18 days later. These adults hibernate in protected situations above the ground, issuing from hibernation next year in May and June. The food of the adults is chiefly pollen.

During the years 1921 to 1923, inclusive, the writer studied the biology of two common species of wireworms, namely, *Melanotus communis* Gyll. and *M. pilosus* Blatch.[1] The larvae of these two species are frequently injurious to young corn plants in Iowa, especially when corn is planted on recently broken ground where the soil is a heavy loam and is in a low and undrained situation. The injury is usually the most serious the first year after the sod has been plowed up and then diminishes in intensity and seriousness during the succeeding years the land is cultivated.

The kernels are first attacked after swelling and are usually completely eaten out. The larvae then attack young plants after germination, eating away the roots and causing the plants to wilt and die. It is characteristic to have certain areas in a field injured. From these spots the larvae work outward enlarging the damaged areas. After the plants get large enough so that they are not killed outright, they are often stunted in their growth and may not tassel out at all. The larvae may bore up into the crown of these older plants.

BIOLOGY

The adults of both species issue from July to early September. Records show 11 beetles issued in July, 58 in August and 15 in September, indicating that a majority mature in August. In the experimental work, the adults were not removed from the tin salve boxes where they were reared until the next spring. They were not fed but an attempt was made to keep the soil around the cell where the beetle was resting in a moist condition. The adults were active, however, and

[1]Family *Elateridae*, Order Coleoptera. This work was done at Ames, Iowa, under the direction of the Iowa Experiment Station and is published with permission of Dr. C. J. Drake, Chief, Entomology Section.

would have escaped at the first opportunity. In nature it is probable that the beetles are active after they mature and instead of wintering in the same cell they matured in, hibernate in various protected situations above the ground. F. D. Butcher, Extension Entomologist for Iowa, collected about 100 adult *M. communis* beetles June 2, 1923, under the bark of a dead maple tree at Columbus, Iowa. These beetles were probably hibernating as it seems unlikely that they would cluster under the loose bark in such numbers if merely resting during the daytime. The writer has frequently collected adults of the genus *Melanotus* under bark of apple trees in the spring while hunting for codling moth larvae.

In the experimental work the beetles were dug up early in April and were placed in cages where they could be watched. Very little signs of activity were noted until sometime in late May, indicating that emergence from hibernation comes rather late in the spring, or as Butcher's record would indicate, early in June. Adults were observed for two years and at no time was there any positive proof that they fed on leaves, although leaves from a number of common trees were given them. On the contrary, they fed readily upon pollen. This was collected for the writer by Wallace Park, of the Entomology Section, from pollen cells in hives of the honey bee. The pollen was kept dry in a stoppered bottle and remained fresh for two years in this condition. In the cages it was placed on small flat sticks of wood. The beetles at once gathered around it and fed for some time. Since under these conditions the pollen moulded in a short time, it had to be replaced frequently. The beetles were kept in cages made by placing a lantern globe over soil in an eight inch pot. Grass was then transplanted in these pots and under this condition the beetles lived in 1923 from May 9 to July 13. At the latter date, there were a few adults still alive but owing to pressure of other work, the experiments were discontinued.

Oviposition takes place in the soil, the beetles burrowing down to a depth of from one to two inches. The eggs are laid singly, are spherical in shape and pearl white in color. Egg laying occurs in June, possibly as late as July. On July 7, when the soil in the cages was first examined, two eggs were found and also a number of young larvae. Most of these larvae had been hatched for only a short time.

When just hatched, and in fact for the rest of that year, the larvae are extremely small and are pale yellow in color. Superficially, they resemble large nematodes more than anything else at this stage. Growth during the first year is very slow and one moult takes place, the larvae

passing their first winter in the second instar. Thirty-four of these young larvae were observed for one year only and the possible period of the larval stage can only be estimated from observations on older larvae covering a period of three years. The smallest and youngest of these larvae collected in late May and early June were very much larger than the first year larvae in November so that they must have been three years old at the least and were possibly older. These larvae grew slowly during the three years they were under observation, moulting from once to twice a year and were still in the larval stage when buried at the end of this period. Assuming that these larvae were three years old when collected in 1921, and that they pupated in 1924, the life cycle for these species covers a period of at least six years.

Pupation of the two species took place between July 6 and August 29, most of the larvae pupating in August. There is one moult prior to pupation followed by a period of activity. Then in late June and early July, the larvae construct an oval cell in the soil, become torpid and finally moult into the pupal stage. For *Melanotus communis*, the duration of the pupal stage ranged from 7 to 39 days with a mean of 18.14 days from forty-two records. For *M. pilosus*, it ranged from 7 to 19 days with a mean of 13.84 days from nineteen records.

PRELIMINARY EXPERIMENTS ON THE USE OF CHLORPICRIN AS AN INSECT FUMIGANT IN FLOUR AND CEREAL MILLS[1]

By A. L. Strand, *University of Minnesota*

Abstract

Chlorpicrin, the "tear gas" of war days, has been very successfully used to combat common insects found in flour and cereal mills. The liquid chlorpicrin, diluted with an equal quantity by volume of carbon tetrachloride, is best applied within the milling equipment by vaporizing the fumigant in the elevator heads while the mill is running. It is this use of the fumigant *within* the machines and elevator legs without fire hazard and without serious personal danger that constitutes its greatest advantage. Small amounts of it can be used to destroy infestations in conveyors, bins, or pieces of idle equipment without interfering with the normal operation of the mill. The preliminary experiments indicate plainly that frequent fumigations with chlorpicrin will keep mill infesting insects down to minimum numbers and greatly increase the intervals at which general fumigations are necessary.

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[1]Published with the approval of the Director as Paper No. 589, of the Journal Series of the Minnesota Agricultural Experiment Station.

Introduction

The high toxicity of chlorpicrin to insects has been well demonstrated by Moore (1918), Bertrand and Rosenblatt (1919) and others. Neifert and Garrison (1920) found it in general to be more toxic to stored products insects than hydrocyanic acid. When the confused flour beetle, (*Tribolium confusum* Duv.), was used as the basis for comparing chlorpicrin with other common fumigants, work at the Minnesota Agricultural Experiment Station has shown that one pound of chlorpicrin at 20°C. is equal to 10 pounds of carbon disulphide or to about 80 pounds of carbon tetrachloride. Besides being so toxic to insects, chlorpicrin is also non-inflammable and non-explosive. Its vapor, while not being very poisonous to man, is, nevertheless, very irritating to the eyes and the respiratory passages so that some precaution must be used in handling it. When these characteristics of chlorpicrin were considered it seemed that it should prove a very useful fumigant in flour and cereal mills if methods could be developed to apply the material without hazard or discomfort to the persons doing the work. Accordingly, some work along this line was started in 1924 as part of a general project on chlorpicrin.

The experiments were suggested by Dr. R. N. Chapman and carried out under his direction. One of the experiments herein reported was performed in a mill which manufactures breakfast food and a variety of other cereal products. All of the other experiments were carried out in a flour mill of 150 barrels capacity per day. This mill, although small, is so constructed that with its five floors it represents very closely one unit or section of a large mill.

Experiment No. 1

This experiment was performed in the flour mill on June 28, 1924. Eight cubic centimeters of chlorpicrin was introduced into each of 21 elevator legs except in one which carried the 2nd tailings stream where 12 cubic centimeters was used. This meant a concentration of 1 pound of chlorpicrin to 1,000 cubic feet of space in 20 of the elevators and 1.5 pounds per 1,000 cubic feet in one of them. The front housing of each elevator head was removed long enough to pour the chlorpicrin onto a small wad of cotton in one of the elevator cups. None of the spouts leading from the elevators was plugged. The elevators were infested with the Mediterranean flour moth. (*Ephestia kuehniella* Zell.), the confused flour beetle, (*Tribolium confusum* Duv.), and a species of *Laemophloeus*. The webbing of the flour-moth larvae on some of the

belting was more than one-quarter of an inch thick. The beetles were most numerous in the boots.

When the elevators were examined 24 hours after the fumigant was applied, all of the flour moths and their larvae were dead except on top of the pulley in the 2nd tailings elevator where live larvae were found. This point was about 18 inches above the place where the chlorpicrin had been applied. A few of the confused flour beetles were killed but those in the boots, together with the *Loemophloeus*, were not affected. No odor of the chlorpicrin was detected in any of the elevators except in the 2nd tailings when the boots were opened for examination.

Experiment No. 2

About six weeks later when the elevators were again infested with flour-moth larvae but to no such extent as in the first experiment, chlorpicrin was applied to four elevators by means of a small DeVilbiss atomizer. A three-eights inch hole was bored into the head of each elevator. Then by fitting a rubber stopper of correct size onto the stem of the atomizer a tight connection was secured when the atomzer was introduced into the hole. With fairly tight packing around the main shaft where it enters each elevator head, it was possible to apply the chlorpicrin without any discomfort to the operator. A concentration of 2 pounds per 1,000 cubic feet of space or 16 cubic centimeters in each elevator was used. Within the elevators a complete kill of flour-moth larvae was secured but only a small percentage of the confused flour beetles was destroyed. However, in spite of the unsatisfactory results against the flour beetles, since the Mediterranean flour moth was by far the major pest in the mill, this experiment was repeated at intervals of from three to five weeks during the summer. Only the low grade streams most subject to infestation were treated. It was found that the flour-moth larvae could be kept down to a point where their numbers in the elevators were negligible and at a surprisingly small cost—about 25 cents per treatment.

Experiment No. 3

As it was desired to find a dosage which would kill all of the insects in the elevators, larger atomizers were secured and in this experiment 4 pounds of chlorpicrin to 1,000 cubic feet of space was applied. Even at this rate all of the confused flour beetles were not killed. It was concluded that probably too much of the gas was escaping from the elevators and going to the machines where many flour moths and their larvae were found to have been killed. With the idea then of

treating the machines at the same time as the elevators and in order to get a more practical and faster method of introducing the chlorpicrin, a new method of application was devised as described in the following experiment.

Experiment No. 4

On May 2, 1925, after discarding the small medicinal type atomizers as being unsuitable for our purpose, a number of atomizing sprayers were obtained. These are also known as 'continuous sprayers' and consist of a one-quart brass container into the top of which is screwed a very simple atomizer. In a cereal mill which was moderately infested with the Mediterranean flour moth and the confused flour beetle, one of these sprayers was set in the head of each of the 23 elevators. All were connected to the same air line as shown in the accompanying figure, the hand-pump attachments on the sprayers having been removed. The air line was connected to a small tank which possessed an air pressure gauge and which in turn was connected to a tank of compressed air. The cubic capacity of all the machinery directly connected by spouting, etc., to the 23 elevators was roughly calculated. A dosage of 5 pounds of chlorpicrin per 1,000 cubic feet contained within the machinery and elevator legs was divided equally among the 23 atomizers. The amount of chlorpicrin necessary was diluted with an equal volume of carbon tetrachloride.[2] When the fumigating equipment was in readiness and the elevators and machines had been made as tight as possible, the mill was started. While the machinery was running the air pressure was released to the atomizers and held at about 15 pounds pressure until the atomizers were empty. Then the mill was closed down and allowed to remain so for about 24 hours.

A good kill of the confused flour beetles was obtained in the elevator legs but in the machines many live ones remained. Checks placed in several of the machines were also alive. But excellent results were secured against the flour moths and their larvae not only in the elevator legs but in the machines as well. Many dead moths were found out on the floor. Much of the machinery in this mill, it should be stated was rather loosely constructed and considerable force of the gas was evidently lost from the equipment.

The arrangement of the fumigating apparatus functioned very well. It was evident, judging from the results against the flour moths, that a good circulation of the gas could be obtained by applying it at the

[2]A mixture of one volume of chlorpicrin with one volume of carbon tetrachloride will vaporize very rapidly when used in the atomizers described.

elevator heads and letting the mill run during the application. The gas is so much heavier than air that when it was forced down the spouts by the operation of the elevators it necessarily found its way through the machines from one floor to the next. The time necessary to apply the fumigant was so short that the wearing of a gas mask was unnecessary.

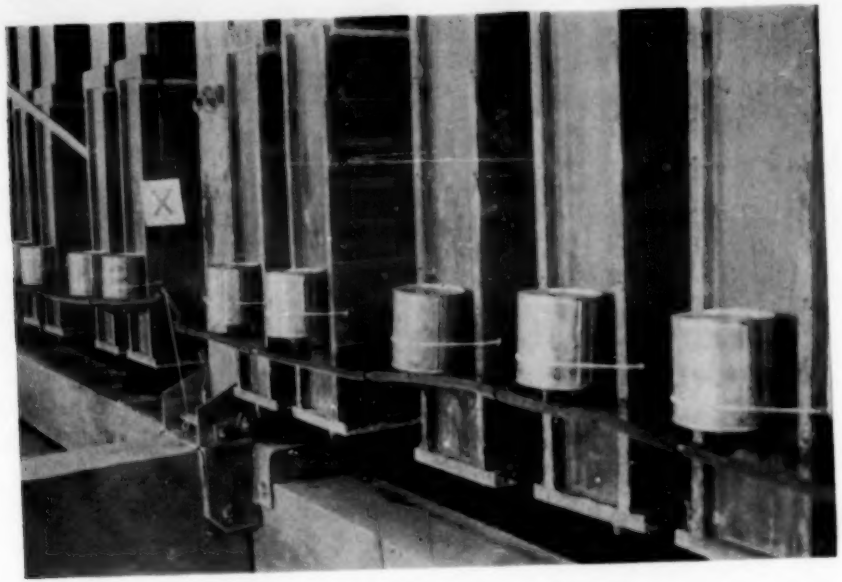
Experiment No. 5

On May 9, 1925, this same method of application was used in the flour mill where the initial experiments were conducted. The same number of atomizers was used as in the cereal mill, the two mills being of about the same size and having the same number of elevator legs. The machinery connected to the elevators in this case was made up of 7 grinding rolls, 6 sifters, 9 bolters, and various conveyors and dusters. Together with the elevators themselves there was a total of about 1,800 cubic feet of space to be fumigated. At the rate of 5 pounds to 1,000 cubic feet, only 9 pounds of chlorpicrin was required. This was diluted with an equal volume of carbon tetrachloride. When the total amount of the mixed fumigant was distributed among the 23 atomizers there was about 200 c.c. of the mixture in each one.

The atomizers and other fumigating equipment were connected as in the previous experiment. A time was chosen for the fumigation when the mill was just about to be closed down. Just prior to shutting down, the supply of grain was cut off and the mill was allowed to run empty. Then while the machinery was still in operation the chlorpicrin was applied. This required about 4 minutes time. As the mill at this time was rather heavily infested with the Mediterranean flour moth and much clogging had occurred we were afraid that the gas might not circulate properly. Consequently just previous to applying the chlorpicrin at the elevator heads a small amount was sprayed into the seven grinding rolls and the six large sifters. While doing this a gas mask was worn.

The results on the whole were very satisfactory. The Mediterranean flour-moth larvae were practically exterminated in the elevators and the machines. In one horizontal conveyor, however, the webbing was so thick that the circulation of the fumigant was impossible. Here no larvae were killed. Although not all of the confused flour beetles were killed, their numbers were greatly reduced. Many dead moths, killed by the gas which escaped from the machines, were found on the different floors of the mill. Upon finding the badly infested conveyor it was promptly sprayed with chlorpicrin and later the whole mill was given a thorough cleaning.

PLATE 8



Atomizing sprayers directed into elevator heads for the application of chlorpicrin. The tubing at X runs to a tank of compressed air by which the sprayers are operated.

Experiment No. 6

This experiment was performed before the mill was again very badly infested in order to test out the circulation of the gas under more favorable conditions than in the previous experiment. The same method and the same amounts of materials were used as in Experiment 5. No chlorpicrin was sprayed directly, though, into any of the machines. The experiment furnished the most satisfactory data of any as yet conducted on what could be done with chlorpicrin as a mill fumigant. Even in some of the most remote equipment, enough chlorpicrin had found its way to destroy the adults and larvae of the Mediterranean flour moth. Very few confused flour beetles could be found after this treatment. It is believed that it was not this fumigation alone which had destroyed them but rather that their reduction was a result of the several periodic fumigations of the mill. The cost of the materials for this treatment was $10.35. The cost of a general fumigation with hydrocyanic acid would have been about four times that amount.

Tests of Other Uses for Chlorpicrin in a Mill

1. Fumigation of empty bins and tanks. For this purpose chlorpicrin at the rate of 2 pounds per 1,000 cubic feet, poured on sacks hung in the top entrances, has controlled all insects common to flour and cereal mills.

2. Treatment of localized infestations in conveyors, idle equipment, etc. In such situations chlorpicrin has been used with very excellent results by allowing it to evaporate from sacks or applying it with a small hand sprayer. If the chlorpicrin is poured on sacks a gas mask need not be worn except perhaps when the sacks are removed if they have been in a rather inaccessible place. When the hand sprayer method of application is used a gas mask is indispensable.

Advantages of Chlorpicrin as a Mill Fumigant

In a fumigation with hydrocyanic acid 100 per cent of the total space within the mill proper must be treated. The actual milling equipment, however, seldom occupies much over 5 per cent of the total cubic capacity of the mill and that part of the equipment most subject to insect infestation may occupy less than 3 per cent of the total capacity. Hence, it is very evident that a highly toxic gas like chlorpicrin which can be used within the infested machines should have a great advantage over hydrocyanic acid in cost per fumigation. While it will not be able to replace cyanide fumigations entirely, by using chlorpicrin to check the insects where they are most numerous and

inaccessible the periods between general fumigations with cyanide can be greatly increased. Yet a better and more even control of the insects can be secured.

By frequent fumigations with chlorpicrin (2 to 4 weeks apart) the insects can be kept down to minimum numbers rather than letting them work up to a peak of abundance and reducing them suddenly with a general fumigation. Such a practice also reduces the necessary amount of cleaning of spouts, elevators, etc.

Finally, the effectiveness of chlorpicrin for controlling small localized infestations which could shortly be the cause of more widespread trouble, gives it exceptional value as a mill fumigant.

Conclusions

Chlorpicrin when vaporized within the milling equipment of flour and cereal mills is a very effective fumigant for controlling the Mediterranean flour moth. It is less effective against the confused flour beetle but several periodic fumigations with chlorpicrin have resulted in a very excellent control of this insect in a mill formerly heavily infested.

Atomizing the chlorpicrin into the heads of the elevators while the machinery is running has been found to be the best method of application.

Chlorpicrin can be used effectively in empty bins or tanks, conveyors, or other pieces of infested equipment.

Methods of application have been found which make the wearing of a gas mask unnecessary.

While further experiments are contemplated in which regular chlorpicrin fumigations are to be carried out over a period of several months, the experiments already conducted have shown that this material can serve as a very useful and effective fumigant in flour and cereal mills.

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ORTHO-TOLUIDINE AS A CONTACT INSECTICIDE[1]

By WALTER E. FLEMING, *Assistant Entomologist, United States Department of Agriculture*[2]

ABSTRACT

Emulsions of ortho-toluidine, an amino-derivative of toluene, were sprayed on the adult Japanese beetle, *Popillia japonica* Newm., to test their value as contact insecticides. The preliminary results in the laboratory indicate that the compound has a definite toxic action on the beetle and that it might prove valuable as a contact insecticide.

INTRODUCTION

Emulsions or solutions of many coal-tar derivatives were sprayed on the adult Japanese beetle, *Popillia japonica* Newm., during the season of 1925 to determine their relative effectiveness as contact insecticides. Since the results obtained in the investigation indicate that one coal-tar derivative, ortho-toluidine, may prove valuable in this connection, this preliminary paper is herewith presented for the consideration of other investigators.

Ortho-toluidine is a chemical compound of known constitution ($C_6H_4.NH_2.CH_3$) which is readily available on the market, being used extensively in the dye industry. It is the ortho-amine derivative of toluene produced by nitrating and then reducing the coal-tar distillate boiling between 110° and 140° C. Freshly distilled ortho-toluidine is a clear, colorless liquid which rapidly becomes yellow to reddish brown on exposure to air and light. It is slightly soluble in water. Aqueous solutions of ortho-toluidine have only weakly basic properties. Ortho-toluidine reacts with acids to form salts, which on account of partial hydrolysis, have an acid reaction in solution. The presence of the amino group in the benzene nucleus makes the rest of the hydrogen atoms more easily replaced by other atoms. Ortho-toluidine is also much more readily oxidized than its corresponding hydrocarbon toluene.

LITERATURE PERTAINING TO ORTHO-TOLUIDINE AS AN INSECTICIDE

When, as a result of these experiments, ortho-toluidine showed promising insecticidal properties as a contact spray, a careful search was made of the literature with the object of determining what had been done along these lines by other investigators. So far as the writer has been able to determine from this examination, the effects on insects of this compound and its derivatives have received scant attention

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[2]The writer desires to acknowledge the assistance rendered by Mr. E. R. Van Leeuwen and Mr. J. M. Conroy, of the Japanese Beetle Laboratory.

from entomologists. Foreman and Graham-Smith (3), in 1918, found that aqueous solutions of ortho-toluidine hydrochloride when imbibed were toxic to the house fly, *Musca domestica* L. Tattersfield and Roberts (4), in 1920, confined wire worms of the genus *Agriotes* in flasks containing known concentrations of ortho-toluidine and found that the vapors evolved had three-fold the toxicity of aniline. Fleming (1), in 1925, tried the action of ortho-toluidine on the immature stages of the Japanese beetle, *Popillia japonica* Newm., and found that vapors and emulsions of the compound were toxic to the insect. The emulsions however, were not effective in killing the immature stages when they were embedded in soil.

Procedure in Determining Toxicity of Ortho-Toluidine Spray

The spray solutions of ortho-toluidine were prepared by diluting 48 cc. of an alcoholic potassium oleate solution (2) to a liter with water, thus making a soap concentration equivalent to 6 pounds per 50 gallons, and then agitating this solution with different amounts of ortho-toluidine to form the emulsions of this compound. The ortho-toluidine content of the solutions was varied progressively from 2.396 gm. to 35.94 gm. per liter (1 pound to 15 pounds per 50 gallons).

All tests with ortho-toluidine solutions as contact sprays were made on a laboratory scale in an outdoor insectary. The beetles were collected in the field just before the treatment and divided into groups of approximately fifty individuals which were placed in cages containing potted smartweed plants, *Polygonum pennsylvanicum* L. The ortho-toluidine solutions were sprayed by means of a hand sprayer on one or more hundred beetles. Two cages of beetles were sprayed with water containing 48 cc. of alcoholic potassium oleate per liter to serve as a control to determine the toxicity of the emulsifier. Two cages of beetles in each series remained unsprayed to serve as a check on the normal mortality of the beetle in each determination under these artificial conditions. The solutions were first sprayed through the wire of the cages, thus wetting the ventral sides of the beetles clinging to the wire, and then the door was opened and the beetles were sprayed on their dorsal sides. In this manner the individual beetles were thoroughly wet by the spray. After the cages were treated, they were left in the outside insectary where the mortality of the beetles in each cage was determined on the first, second, and third subsequent days.

Toxicity of Ortho-toluidine Emulsion

The results of the laboratory tests with spray solutions containing different concentrations of ortho-toluidine indicated that at least 23.96 gm. of ortho-toluidine must be dispersed in a liter of the soap solution (10 pounds in 50 gallons) in order to kill the beetle. The number of deaths which resulted from the use of this concentration, the number which resulted from the use of potassium oleate only, and the number which occurred among the untreated beetles are outlined for seventeen series of tests in Table 1.

Table I. Toxicity of Ortho-Toluidine Spray to the Japanese Beetle.

Date of test	Beetles sprayed with solution of o-toluidine 23.96 gm per liter potassium oleate 14.37 gm. per liter				Beetles sprayed with solution of potassium oleate 14.37 gm. per liter (control)				Beetles not sprayed (check)			
	No. of beetles in test	Mortality 24 hr. %	48 hr. %	72 hr. %	No. of beetles in test	Mortality 24 hr. %	48 hr. %	72 hr. %	No. of beetles in test	Mortality 24 hr. %	48 hr. %	72 hr. %
1925												
July 23	107	95	95	95	92	11	39	77	145	0	3	8
July 27	198	69	77	88	100	10	55	74	146	0	2	6
July 28	197	100	100	100	98	8	35	80	93	0	9	20
July 29	194	76	93	94	214	25	65	84	150	3	9	13
July 30	199	100	100	100	199	27	44	81	139	2	4	29
July 31	200	100	100	100	204	31	35	63	146	0	11	29
August 1	212	91	93	93	202	30	60	83	124	0	8	19
August 3	192	90	93	94	97	48	70	93	147	0	12	18
August 6	104	91	95	100	—	—	—	—	136	6	19	54
August 8	198	62	70	74	177	26	37	59	191	12	25	30
August 10	196	66	78	90	223	36	73	90	136	10	31	42
August 12	197	93	96	97	193	30	78	95	153	0	14	32
August 14	99	72	85	96	110	18	65	93	110	6	25	37
August 16	97	92	97	99	109	19	43	74	153	5	21	55
August 17	98	87	96	100	100	54	91	96	118	12	31	70
August 18	95	89	91	96	100	73	98	100	54	7	17	47
August 20	135	90	94	100	97	88	98	100	102	5	10	75
Average of series	160	86	91	95	144	33	61	83	131	4	15	37

As will be seen by an examination of the death rates among the untreated insects, the beetles do not readily endure extended confinement. Thirty-seven per cent of the beetles collected in the field and confined in cages, although unsprayed, were dead within 72 hours. However, there was considerable variation in the mortality occurring in different groups of unsprayed beetles. In all probability, this variability can be attributed to the difference in the size, age, environment,

and activity of the beetles collected at random in the field. It will be observed also that in general the normal death rate of the beetle increased as the season progressed until towards the end of August the majority of the beetles confined were dead at the end of 72 hours. In view of these factors, it was necessary to base any conclusions on observations made on several groups of beetles throughout the season.

When the beetles were sprayed with a solution containing 14.37 gm. of potassium oleate (48 cc. of the alcoholic solution) per liter, equivalent to 6 pounds per 50 gallons, 33 per cent were dead at the end of 24 hours, 61 per cent within 48 hours, and 83 per cent within 72 hours. If one considered the mortality caused by the soap solution 72 hours after spraying without examining the deaths in the check, he would be likely to conclude that the soap solution was a good contact insecticide for the Japanese beetle. However, when the percentage of beetles killed in the control cages is compared with that of the unsprayed beetles, it is doubtful whether one can properly attribute mortality of 83 per cent to spraying with a solution containing 6 pounds of potassium oleate. In view of the relatively low mortality in the checks during the first 48 hours, it is very probable that the number of beetles dead in the control cages at the end of this period (61 per cent), is a more accurate indication of the killing power of this concentration of potassium oleate.

The addition of 23.96 gm. of ortho-toluidine to a liter of this soap solution, equivalent to 10 pounds to 50 gallons, gave, on an everage, the following results: 86 per cent dead within 24 hours, 91 per cent dead within 48 hours, and 95 per cent dead at the end of 72 hours. The high mortality which occurred at the end of 24 hours was evidently caused by the ortho-toluidine in the spray. This solution was also more consistent in killing a high percentage of beetles at different periods throughout the summer than were solutions containing an equivalent amount of potassium oleate. The mortality caused by this compound when sprayed on a heavily chitinized insect like the adult Japanese beetle suggests that more dilute solutions might be effective in killing aphids and other soft-bodied insects.

Physiological Action of Ortho-Toluidine Emulsion on the Beetle

The actions of a Japanese beetle sprayed with an ortho-toluidine emulsion are entirely different from those of one sprayed with a soap solution. When the beetle is sprayed with an ortho-toluidine emulsion, it immediately becomes unusually agitated and moves rapidly about as if in pain. Within a few minutes, depending of course on the con-

centration used, its locomotion becomes awkward, uncertain, and slow. It attempts to cling spasmodically to the foliage or to the side of the cage; saliva exudes from its mouth. In a short time, it loosens its grasp and drops to the ground, where it lies, turned usually on its back, with an occasional quivering of its legs and mouth parts. When this stage is passed, all motion ceases. Within a short time the elytra lose their bronze luster and the whole body becomes mottled with dark, irregularly distributed blotches.

The Action of Ortho-toluidine Emulsion on Foliage

Preliminary observations on the action of ortho-toluidine emulsion on foliage were made during the course of the experiments to determine the effect of the sprays on the beetle. It was described, when discussing the procedure of determining the toxicity of the ortho-toluidine spray to the beetle, how smartweed plants were placed in the cages with the beetles and sprayed. In general, within a period of 7 days, no signs of injury could be observed on smartweed leaves sprayed with solutions containing 23.96 gm. per liter (10 pounds per 50 gallons of ortho-toluidine). This concentration, however, seemed to cause a slight amount of injury to the foliage of apple and peach. Nevertheless, it is not expected that it will cause any serious damage to foliage.

Summary

Emulsions of ortho-toluidine, an amino-derivative of tolune, were sprayed on the Japanese beetle to test their value as contact insecticides. The preliminary results in the laboratory indicate that the compound has a definite toxic action on the beetle and that it might prove valuable as a contact insecticide.

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ON THE POSSIBILITY OF DEVELOPMENT OF TOLERANCE TO ARSENIC BY INDIVIDUAL INSECTS[1]

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ABSTRACT

An unsuccessful attempt was made to induce a detectable tolerance to arsenic in individual silkworms (*Bombyx mori*) by administering by mouth a number of sublethal doses of neutral sodium arsenate solution during the course of larval development.

INTRODUCTION

Considerable interest was evoked at the Christmas Meetings of the American Association of Economic Entomologists, 1913–14, by Melander's report (1914) of a few "feeler" experiments by Glaser,[2] which seemed to the former to have demonstrated that individual gipsy-moth caterpillars can become immune to the effects of lead arsenate under the influence of sublethal doses of that poison. Glaser himself, however, was never convinced that he had proved or disproved the development of immunity or of tolerance to arsenic, and consequently the results of his experiments were never published.

Quantitative methods, essential for the experimental study of the tolerance question and hitherto lacking, became available when it was observed (Campbell, 1926a) that caterpillars can be caused to drink completely drops of arsenical solutions. This paper presents the results of attempts to induce tolerance to arsenic in the silkworm by feeding it known sublethal doses of neutral sodium arsenate solutions. The methods of feeding and of measuring the doses have been described in detail (Campbell, 1926b). Briefly: drops of calculated volume were removed from the fine tip of a micro-burette by a platinum needle, and were placed upon the mouthparts of a weighed silkworm, which imbibed the drops completely.

THE CRITERION OF ACQUIRED TOLERANCE TO ARSENIC

If it could be shown that a group of silkworms which had taken a number of known sublethal doses of arsenic at various times during

[1]Contributions from the Entomological Laboratory of the Bussey Institution, Harvard University, No. 257.

[2]The writer is indebted to Dr. R. W. Glaser, Rockefeller Institute for Medical Research, Princeton, N. J., for information concerning the experiments of the latter on gipsy-moth caterpillars; to Professor Reid Hunt, Harvard Medical School, for his opinion on arsenic toleration in medical practice; and to Professors W. M. Wheeler, C. T. Brues, and W. J. Crozier, Harvard University, and Professor T. J. Headlee, Rutgers University, for their criticisms of this paper.

its developmental period was more resistant to the effects of a final known dose of arsenic than a similar group which had not received protective sublethal doses, there would be conclusive evidence that more or less tolerance had been acquired by the former group. The difference in resistance of the two groups would be most convincingly demonstrated if the final dose of arsenic were of such a magnitude that the "immunized" group would recover from it, and the previously unpoisoned group would die. Several attempts were made to determine the size of this critical dose. They were unsuccessful, because both groups either died or recovered; and it seemed impossible to choose a median dose which would affect the two groups unequally. Thus it was evident that the silkworm will not develop any marked tolerance to arsenic, to say nothing of immunity. Therefore it was decided that if any acquired tolerance were to be detected, a more delicate criterion would have to be adopted than that of death or recovery—a criterion depending on a differential effect of a final sublethal dose.

That sublethal doses of arsenic may have a definite effect on insects seems to have been first suggested by Moore (1922). After close observation of the feeding habits of the Japanese beetle on foliage sprayed with arsenicals, he concluded that many beetles escaped death because the toxic effects of sublethal quantities of arsenic prevented feeding before a lethal dose could be consumed. Moore's interpretation of the facts is undoubtedly correct, because the most invariable and characteristic result of administering sublethal doses in solution to the silkworm is to cause the insect to cease feeding for a greater or less length of time depending on the size of the dose.

Since silkworms eat so voraciously and grow so rapidly, the effect of inhibition of feeding by sublethal doses of arsenical solutions is quickly and measurably reflected in decrease of normal growth rate. It was thought, therefore, that the relative change in weight of an "immunized" and of a previously unpoisoned group of silkworms, simultaneously under the influence of a final sublethal dose, would provide the desired sensitive criterion of tolerance; for, if the change in weight of the "immunized" group were significantly greater than that of the previously unpoisoned group, a certain amount of tolerance might then be said to have been induced in the former group.

Experimental Results

The results of an experiment in which this criterion was used are presented in Table 1, to which reference should be made while reading the following description: Two groups of silkworms, each composed

of 16 individuals in the second day of the second instar, were selected so that the individual and average weight of the worms was practically the same in both groups. One lot, "B", was to be "immunized" by sublethal doses, the other, "A", was to serve as a control to show the extent of effect of sublethal doses on "B". On July 8 the individuals of group B were fed 0.0025 mg. of arsenic per gm. of worm (about ¼ of the minimum lethal dose for the second instar) in a volume of solution equal to 5 mm. per gm. of worm. Group A was fed the same volume of water. After 24 hours all of the worms were weighed again. Group B gained 49.5% in weight, while the controls increased their weight by 60%, indicating definitely some inhibition of feeding even by so minute a dose. Stimulation of growth by sublethal doses was never encountered, perhaps because sufficiently small doses were not used.

TABLE 1. A GROWTH TEST FOR DEVELOPMENT OF TOLERANCE TO ARSENIC IN THE SILKWORM. "A," CONTROLS; "B," WORMS FED 4 SUBLETHAL DOSES BEFORE THE CRITICAL TEST FOR TOLERANCE; "C," WORMS UNPOISONED BEFORE THE CRITICAL TEST FOR TOLERANCE

PART 1: "IMMUNIZATION" OF GROUP B

Instar		Second				Third			
Date		July 8		July 9		July 13		July 14	
Group		A	B	A	B	A	B	A	B
Sub-lethal dose		Water	0.0025 mg. As per gm.	Water	0.0025 mg. As per gm.	Water	0.0050 mg. As per gm.	Water	0.0075 mg. As per gm.
	No.								
	1	11.5	14.1	18.5	19.1	60.9	60.8	60.0	58.9
	2	12.6	11.5	20.6	17.5	89.8	65.1	113.6	61.2
	3	16.8	12.9	23.3	18.2	94.5	43.7	138.0	62.5
	4	13.7	14.2	22.4	18.7	100.3	67.0	93.7	86.4
	5	14.1	14.2	22.6	19.7	97.4	75.0	89.7	100.2
	6	13.6	9.9	14.6	13.2	50.9	34.7	73.3	43.3
Wt.	7	11.5	13.0	19.0	16.6	61.2	45.6	119.5	65.2
of	8	15.1	11.7	25.6	16.9	85.0	61.0	123.0	74.2
worms:	9	10.1	11.1	18.4	20.0	63.9	69.3	80.4	103.0
milli-	10	9.5	10.4	16.4	16.9	69.8	60.5	74.6	67.9
grams	31	8.8	11.3	14.8	16.8	51.2	46.7	76.3	68.7
	12	11.4	11.7	20.8	20.0	71.9	72.8	120.3	92.5
	13	11.5	12.0	19.7	18.6	73.0	56.9	87.3	61.0
	14	9.8	14.2	15.3	24.2	44.6	76.0	87.1	72.2
	15	10.2	8.8	17.0	15.2	60.0	36.8	68.0	35.7
	16	11.2	9.2	17.7	13.9	54.3	39.8	92.1	61.5
Average weight		12.0	11.9	19.2	17.8	70.5	57.0	93.5	69.7
% Wt. gained between weighings				60.0	49.5	267.4	220.0	32.6	22.3

PART 2: CRITICAL TEST FOR TOLERANCE

Instar				Fourth			
Date		July 19			July 20		
Group		A	B	C	A	B	C
Sublethal dose			0.0100	0.0100			
		Water	mg. As per gm.	mg. As per gm.			
	No.						
	1	192	161	142	277	149	165
	2	530	231	216	618	207	192
	3	645	223	216	811	196	278
	4	517	249	245	753	261	264
	5	525	308	337	700	270	342
	6	267	112	118	424	130	108
Wt.	7	520	217	221	710	196	215
of worms:	8	538	335	365	744	334	362
milligrams:	9	352	363	368	509	378	397
	10	377	261	258	548	265	291
	11	400	90	88	568	90	91
	12	572	183	177	721	225	197
	13	317	205	212	425	184	225
	14	327	283	279	497	283	255
	15	154	98	100	244	78	101
	16	357	185	195	564	192	193
Average weight		411	219	221	570	215	230
% wt. gained between weighings		340	214		38.7	—1.8	4.1

Since all of the worms were feeding normally at the time the weighings were made, another sublethal dose of the same size was administered to "B" and water to "A" as before. Weighings the next day were prevented by the beginning of ecdysis. Retardation in development of group B was further evinced by the later inception of ecdysis among its members. As an extreme instance of this effect, the case of a poisoned worm in another experiment may be cited. It hovered between life and death for several days without eating, and when it finally recovered and began to feed again, it was a full instar behind the other unpoisoned worms with which it had hatched.

Three days later when all of the worms of both groups were well into the third instar and were feeding normally, a larger sublethal dose, 0.0050 mg. arsenic per gm., was administered to group B. The toxic effect was again apparent in the difference in percentage weight gained during the next 24 hours by "A" and "B". The sublethal dose was again increased to 0.0075 mg. arsenic per gm. Ecdysis began in the controls the next day, but not in group B, which was at that time about two days behind "A" in development.

When all of the larvae were in the fourth instar and were feeding vigorously, another group of silkworms, "C", was selected from a previously unpoisoned lot which had hatched later than the individuals of "A" and "B", so that its members were about equal in weight worm for worm with those of group B which had received 4 sublethal doses. The critical test for the development of tolerance was then applied. The individuals of groups B and C were fed alternately a sublethal dose of 0.0100 mg. arsenic per gm. (from ½ to ¾ of the minimum lethal dose for the fourth instar). Weighings 24 hours later showed the usual heavy gain in weight of the controls, whereas "B" and "C" had not changed significantly in weight, the difference in the change of their mean weight being 13.1 ± 5.1 mg. by Bessel's formula. Indeed, if the slight difference in percentage change of weight between "B" and "C" were significant, it would mean that the so-called immunized group was slightly less resistant to the effects of the critical dose than the previously unpoisoned group. Therefore by the growth criterion no tolerance whatever was developed by group B.

Discussion

The failure to prove the development of even a slight amount of tolerance to arsenic was not unexpected, because it is known that inorganic poisons, such as arsenic, do not stimulate the formation of specific protective antibodies as do proteins (Wells, 1925). Melander's use of the term "arsenic antibody" was therefore incorrect. Acquired tolerance to arsenic, if it occurs at all, must arise in some other way than by the formation of compounds in the insect which combine with the poison and render it innocuous. For example, irritation of the gut epithelium by sublethal doses might make its penetration by subsequent doses of arsenic more difficult. Schwartze (1923) has studied the question of so-called arsenic habituation in mammals, and has thoroughly reviewed the literature of the subject. He concluded that neither in his own nor in other experiments had acquired arsenic toleration been convincingly demonstrated. The notion that Styrian "arsenic eaters" can acquire marvelous resistance to the effects of arsenic is a popular fallacy. When an arsenic eater takes an apparently enormous dose of solid arsenious oxide, he is in reality taking a sublethal dose of soluble arsenic, because most of the relatively insoluble arsenious oxide passes through the alimentary tract unchanged. The toxicity of arsenious oxide was found by Schwartze to depend on the size of its particles; a point which ought to be considered in dealing with the relative toxicity of commercial

arsenical insecticides. Colloidal arsenicals should be most toxic.

According to Hunt,[2] acquired toleration of arsenic is not expected in the medical application of arsenicals, but, instead, some cumulative action. Administration by mouth or by injection of Fowler's solution failed to induce tolerance to arsenic in dogs (Daga, 1925). In view of the overwhelming evidence against acquired toleration, it does not seem surprising to the writer that no tolerance was developed by the silkworms of group B, but rather that elimination of the previous sublethal doses was so complete that almost no cumulative effect was evident in the final comparison. Nevertheless, the writer does not wish to assert that individual tolerance to arsenic cannot be acquired by silkworms, because the effects of sublethal doses in infinite variety of magnitude, number, and sequence might be tested, some combination of which might reveal slight tolerance. Moreover, insoluble commercial arsenicals might give rise to some form of tolerance which soluble arsenicals could not induce, though it is hard to see how this could happen. It is unlikely, however, that individual tolerance to a degree which would have economic significance can be acquired by insects. The fact that it is more difficult in practice to kill older caterpillars than younger ones cannot be ascribed to the development of tolerance to arsenic, because it is harder to kill older caterpillars regardless of whether they have been previously exposed to poisoned foliage or not. The real reason for the difference in susceptibility probably lies in the fact that the minimum lethal dose of arsenic per unit weight of insect increases during the larval period. Campbell, 1926 C.

The development of racial resistance to arsenic by "toxic" selection of the more resistant individuals for reproduction is an entirely different matter from the development of tolerance by individuals, as Melander pointed out. It is conceivable that the average resistance of an economic insect to arsenic might be raised by selection in a locality where spraying is persistently practiced. Woglum (1925) believes that the average resistance of the red and of the black scale to HCN has been raised by "toxic" selection in certain parts of California; but the problem of racial tolerance to insecticides will have to be studied by quantitative laboratory methods before it can be conclusively solved.

Conclusion

Individual tolerance to arsenic was not induced in silkworms by quantitative feeding of sublethal doses of sodium arsenate solutions.

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A FIELD METHOD FOR DETERMINING THE OIL STRENGTH OF SPRAYS

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ABSTRACT

The Babcock method for the determination of butter-fat in milk and cream is modified to give the per cent by volume of oil in concentrated and spray-strength petroleum oil emulsions. The modified method is adaptable to emulsions containing soap, cresol, glue and probably other organic emulsifying agents, and can be used during spraying operations in the field. It is simple and can be used by non-technical men.

Owing to the growth, in recent years, of the use of lubricating oil emulsions as sprays it has become important to have a quick and simple method for the determination of oil in both concentrated emulsions and diluted sprays. Such a method would serve as a check on the strength of concentrated material either as purchased or as made at home and also as a check on the strength of the oil actually being applied in the diluted spray. The method must be one that can easily be taught to men who have had no chemical training and must require comparatively inexpensive apparatus.

The Babcock method which fulfills the requirements of being simple and inexpensive has long been used by practical dairymen and milk testers for determining butter-fat in cream and milk. G. E. Colby and J. W. Elmore,[1] have recommended a modification of this method for the determination of oil in concentrated emulsions. We have further modified the method to make it applicable to field use and have extended it to include diluted sprays. The determinations are made on a volume basis because the entomologist or orchardist is interested to know what per cent by volume of oil he is getting.

Concentrated Emulsions

The apparatus and materials required, all of which may be readily obtained from any chemical supply house, are as follows:

A 25 cc graduated cylinder.
A 10 cc capacity pipette
A Babcock milk tester (hand centrifuge)
Babcock cream test bottles, 50% 18 grams (50%, 9 gram bottles may be used, in which case a 5 cc pipette should be employed.)
Commercial concentrated sulphuric acid.

In the Summer of 1925, this outfit cost us $17.00.

In the case of lubricating oil-soap emulsions, 10 cc of the emulsion (5 cc if 9 gram, 50% bottles are used) is pipetted into the cream test bottle and the pipette is thoroughly rinsed with 10 cc of water, which is also transferred to the cream test bottle. To this is added 20 cc of the concentrated sulfuric acid diluted 1 volume to 4 volumes of water. The mixture is well shaken and water, preferably hot, is added until the bottle is filled nearly to the top of the graduations. The bottle is then whirled in the milk tester for 2 minutes and the volume of the oil and fatty acids separated in the neck of the bottle is read. The oil reading multiplied by two gives the percentage of oil and fatty acid present. In the case of emulsions made by the Government formula,[2] the fatty acids constitute about 4 per cent of the separated oil and may be corrected for by multiplying the observed volume by 0.96. Thus the cream test bottle reading multiplied by 1.92 (2 times 0.96) is the approximate percentage of oil in the material.

In this determination the diluted sulfuric acid may be replaced by either diluted or concentrated hydrochloric acid. Concentrated sulfuric

[1]Graham, J. J. T., Journal of the Assoc. Off. Agr. Chemists, Vol. 8, pp. 333-343, May, 1925.

[2]Yothers, W. W., Spraying for the control of insects and mites attacking citrus trees in Florida. U. S. D. A., Farmers' Bulletin 933, 44 pp. (Revised June 1922).

acid may be used, but it is not recommended because, at times, insoluble material is formed which makes it difficult to read the volume of oil.

The oil in miscible oils of the soap-cresol-oil type may be determined in the same way as that in soap-oil emulsions. The volume of the cresol present may be neglected because most of it has been found to dissolve in the acid layer.

In the presence of glue, and probably of other organic emulsifiers, the 20 cc of diluted sulfuric acid is replaced by 20 cc of concentrated sulfuric acid. The acid is added gradually with shaking after each addition. The rest of the determination is the same as before, except that if no soap is present the factor 0.96 is omitted.

Some of the results obtained by the proposed method follow:

Type of emulsion	Oil present by chemical analysis	Oil determined by proposed method using			
		Dilute sulfuric acid	Conc. sulfuric acid	Dilute hydrochloric acid	Conc. hydrochloric acid
	Per cent	Per cent	Per cent	Per cent	Per cent
Lubricating oil-soap.....	67.0	67.8	67.4	——	66.0
Lubricating oil-soap.....	67.5	67.0	66.4	——	67.2
Lubricating oil-cresol-soap..	59.4	58.8	60.3	58.6	——
Lubricating oil-soap-glue....	61.4	No separation	61.8	No separation	——

The results obtained by the proposed method are in every case very near to those obtained by chemical analysis, certainly close enough for field purposes.

Spray Strength Emulsions

The apparatus used is the same as that used for the concentrated emulsions, except that an 8%, 18 gram milk bottle is used in place of the cream bottle and a 20 cc capacity pipette in place of the 10 cc one.

Twenty cc of the spray strength emulsion are pipetted into the milk test bottle. To this is added gradually, with shaking, 20 cc of commercial concentrated sulfuric acid. The bottle is then filled nearly to the top of the graduations with hot water and whirled in the milk tester for 2 minutes. The volume of oil separated in the neck of the bottle is read and is equal to the per cent by volume of oil and fatty acids in the spray. (If a small pellicle is present between the oil and the acid layer its volume is included with that of the oil.) The volume is corrected for fatty acids by multiplying by 0.96.

Concentrated sulfuric acid is used in this determination because the heat produced when it is mixed with the spray renders the oil less viscous and easier to separate. When cold dilute acids are used the results are

slightly lower than they should be. Probably if the bottles were heated in a water bath accurate results would be obtained with cold dilute acids.

This method has been successfully used with lubricating oil-soap emulsions, lubricating oil-soap-glue emulsions, and lubricating oil-cresol-soap emulsions. It would probably be effective with emulsions containing most other organic emulsifiers. Of course in the absence of soap the factor 0.96 would not be used. Some of the results obtained by the proposed method follow:

Type of emulsion	Oil present	Oil determined by proposed method
	Per cent	Per cent
Lubricating oil-soap	1.67	1.63
" " "	3.33	3.27
" " "	1.69	1.63
" " "	3.38	3.36
Lubricating oil-soap-glue	3.09	3.07
" " " "	1.55	1.54
Lubricating-oil soap-cresol	1.49	1.49

As the bottle is read only to 0.05 per cent, these results are well within the experimental error.

These methods have been tried in the field by Dr. B. A. Porter and Mr. H. K. Plank of the Bureau of Entomology. Both report favorable results.

MODIFICATIONS OF METHODS FOR MAKING COLD-MIXED OIL EMULSIONS[1]

By CHARLES H. RICHARDSON, *Entomologist, Fruit Insect Investigations, Bureau of Entomology*, and

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ABSTRACT

A cold-mixed lubricating oil emulsion can be made by the addition of 8 liquid ounces of crude cresylic acid, cresol U. S. P., or cyclohexanol to the usual proportions of potassium fish oil soap and oil called for in the boiled emulsion formula, adjusting the water content to give about 68 per cent oil by volume. The paste of oil, soap, and cresylic acid first obtained may be diluted at once with water to form a stock emulsion, or stored for future use. It will keep indefinitely if evaporation is prevented but should be mixed with a little water before being poured into the spray tank. When diluted to spray strength, this emulsion has the stability and small droplet size characteristic of diluted miscible oils. Any petroleum oil from kerosene to lubricating oil of high viscosity can be used to prepare this emulsion. A good cold-

[1]The writers are indebted to Mr. R. C. Burdette, Bureau of Entomology, for assistance in the preparation of emulsions and in the insecticidal experiments.

mixed emulsion can also be made with two gallons of oil and one quart of potassium fish oil soap. The soap-oil paste may be stirred at once into 3 quarts of water to make a stock emulsion or held for future use. Such emulsions appear to be as stable as those prepared according to the usual boiled emulsion formula.

A cold-mixed lubricating oil emulsion of a new type has been reported by Whitcomb.[2] The formula calls for lubricating oil, potassium fish oil soap, and water in the same proportions as are used in the Government formula for boiled emulsions[3] and, in addition, for amyl alcohol (fusel oil) in the proportion of four ounces to each gallon of oil. Excellent emulsions can be made by this formula without heating. It seemed possible, however, that a less expensive and more readily obtainable material could be used in place of the amyl alcohol.

Soap-cresol-oil Emulsions

Experiments were conducted in which various compounds were added in place of the amyl alcohol. The following materials gave emulsions equal in stability and in physical properties to those obtained by the use of the Whitcomb formula: Crude cresylic acid (both the 95% dark and the 97–99% straw grades); cresol, U. S. P., and cyclohexanol. Of these, crude cresylic acid is at present the most economical and the following formula is recommended:

Lubricating oil	2 gallons
Potassium fish oil soap	1 quart (about 2 pounds)
Crude cresylic acid	8 liquid ounces, (½ pint.)
Water	5 pints

The cresylic acid is first mixed thoroughly with the soap. A jelly-like material results. The oil is added gradually, the mixture being stirred vigorously and thoroughly after each addition. The first addition should not be more than half the volume of the soap. The following additions may be larger. When all the oil has been stirred in a paste results. The principal precautions to be observed are that the proportion of cresylic acid shall not exceed that stated and that the first additions of oil shall be small.

The paste thus obtained contains about 86% of oil by volume, and in tightly closed containers, may be stored for a long time without deterioation. (If a little oil separates on standing it may be stirred in again without injury to the product.) It may be diluted to a concentrated

[2] A new formula for making lubricating oil emulsions. Jour. Econ. Ent. Vol. 18, No. 1, pp. 234–235, 1925.

[3] Yothers, W. W. Spraying for the control of insects and mites attacking citrus trees in Florida. U. S. D. A., Farmers' Bulletin 933, 44 pp. (Revised June 1922).

emulsion by stirring in the five pints of water. If the water is stirred in gradually good mixing is attained more easily than if all is added at once. When so diluted the emulsion contains about 68% of the oil by volume and can readily be diluted to spray strength.

At spray strength (2 to 3 per cent oil) the emulsion is milky white and the oil droplets are of the small size characteristic of miscible oils (mainly 2 microns and less in diameter) and remain evenly dispersed through the water for a long time. Because of the high degree of dispersion of the oil, this emulsion is relatively resistant to breaking in hard water, behaving in this respect like a miscible oil.

In making this product apparently any petroleum oil from kerosene to a heavy lubricating oil may be used. The following oils have been tried with good results: Kerosene; gas oil of 0.879 sp. gr. and 50 secs. viscosity (Saybolt at 100°F); a medicinal liquid petrolatum of 0.879 sp. gr. and 218 viscosity; several brands of widely used lubricating and red engine oils of paraffin or mixed base; and a naphthenic base lubricating oil. The oil to be chosen will depend on its effectiveness as an insecticide and its cost in the particular locality.

The soap used is the ordinary liquid fish oil soap containing 60 to 70 per cent of water and a little free alkali. Stable emulsions have also been obtained with various other soaps. Apparently the main consideration is that, at the strength used, it shall be sufficiently liquid to mix well with the cresol and oil.

Soap-Oil Emulsions

In testing various materials to determine whether they could replace the amyl alcohol used in the Whitcomb formula, it was found that in almost all cases except those listed under "Soap-cresol-oil emulsions," an emulsion was obtained which was the equivalent of a good boiled emulsion. This suggested that the added material had no effect on the emulsion and that a good emulsion could be made with soap and oil alone in these proportions.

Such a method of preparation would appear to have certain advantages over the present methods of preparing lubricating oil emulsions according to the Government formula[4] which require the use of heat or a large proportion of soap. In the preparation of the boiled emulsion, the use of heat is both time-consuming and expensive, while the increased proportion of soap demanded by the cold-mixed emulsion formula adds to the cost of the product.

[4]Yothers, W. W., loc cit.

It was, in fact, found that excellent emulsions could be obtained as in the Whitcomb method without any additional material. The following modification of the present formula for making cold-mixed emulsions is therefore offered:

Lubricating oil	2 gallons
Potassium fish oil soap	1 quart (about 2 pounds)
Water	3 quarts

Apparently any petroleum fraction from kerosene up to the very heavy lubricating fractions will make a good emulsion. Potassium fish oil soap was used. As in the case of "Soap-cresol-oil emulsions," it was found that various kinds of soap could be used, provided they had the consistency of a soft paste so as to mix well with the oil.

The procedure is as follows: Pour the soap into a tub or pail. Add the oil gradually, the first addition being not more than one-half the volume of the soap. Stir vigorously and thoroughly with a paddle.[5] Then add the rest of the oil somewhat more rapidly, stirring after each addition until all the oil has disappeared into the paste. When made as directed a good emulsion results. If the oil has been added too rapidly, however, it may fail to work into the paste. In that case take about one-half the original quantity of soap and add the imperfect soap-oil paste gradually, stirring after each addition.

When made in this manner, the jelly-like paste contains about 89 per cent of oil by volume. It may be stored in tight containers and later carried into the field to be diluted to spray strength. It is desirable to fill each container full of the paste to prevent evaporation and the consequent separation of some of the oil. If oil is visible on the surface however, it can easily be stirred into the paste again. This paste may be prepared before the spraying season; in fact, the writers have samples that have been kept more than four months in loosely closed jars, from which perfect spray-strength emulsions can still be made.

Before placing the paste in the spray tank, it is essential to dilute it with a little water. The diluted emulsion is then poured into the tank, the tank is filled to the required volume with water, and the whole mixture is thoroughly agitated before spraying.

If preferred, the oil-soap paste may be mixed at once with water to form a concentrated emulsion. By employing the proportions in the foregoing formula, an emulsion containing about 67 per cent of oil by volume is obtained.

[5] The product can be emulsified even near freezing temperatures if the stirring is very vigorous. However, under such conditions emulsification will take place more easily if the soap is warmed somewhat by placing it near a fire before using.

Where soft water is available less soap may be used in the preparation of the oil-soap paste. At Washington, D. C., the writers have obtained stable spray-strength emulsions with pastes containing one-half the quantity of soap given in the above formula when mixed with tap water. A greater reduction in soap content than this is not recommended, however. Where hard waters must be used, the quantity of soap may be increased, but it is probably more economical, under these conditions to add a stabilizer. The stabilizers may be mixed into the oil-soap paste if it is to be used at once.

Cold-mixed emulsions prepared according to the given formula appear to be as stable as the best boiled emulsions. As the stability of a petroleum oil emulsion depends largely upon the size of the oil droplets, a comparison was made of droplet size in the cold-mixed emulsions with that in well made samples of boiled emulsions. In both the oil droplets had a diameter of about 8 microns, indicating that the degree of dispersion was nearly equal.

Spraying experiments with *Aphis rumicis* show that the cold-mixed soap-cresol emulsion is as efficient as the emulsion made with amyl alcohol and that the cold-mixed soap-oil emulsion has approximately the same toxicity as the boiled emulsion, provided the soap and oil are used in the same proportions in both cases.

REPELLENT SPRAYS FOR FLIES ATTACKING DAIRY CATTLE

By C. R. CLEVELAND, *Purdue University Agricultural Experiment Station, Lafayette, Indiana*

ABSTRACT

The protection of dairy cows from attack by blood-sucking flies, especially the horn fly, *Haematobia irritans* and the stable fly, *Stomoxys calcitrans*, is a live problem. The use of repellent sprays appears thus far to offer the only feasible means of control in the majority of cases. The practice of using some kind of repellent cattle fly spray is more prevalent than might be supposed, but the choice of a spray has heretofore been governed largely by the chance availability of some particular brand of proprietary material rather than of considerations based on comparative cost, effectiveness and practicableness.

Two seasons' tests conducted under practical farm conditions have resulted in clarifying knowledge concerning the general feasibility and value of spraying on the average dairy farm as well as the comparative effectiveness, cost and practicableness of various fly spray formulae.

The more promising commercial and home-mixed materials were tested. Of all these a new, exceedingly inexpensive spray composed of used crank case oil and oil of tar in proportions of one gallon to one pint, has offered the most promising results in terms of effectiveness, cost, and practicableness from every standpoint.

While exact experimental evidence tending to show the relationship existing between the attack of blood-sucking flies and the productive

powers of the dairy cow appears to be largely lacking, it is generally conceded and well-nigh universally believed through processes of deductive reasoning, by dairy men and entomologists alike, that flies are responsible for considerable loss in terms of decreased weight and milk flow.

And even though no consideration were given to the economic results of fly annoyance, it is felt by the majority of humane and progressive dairy farmers that the reduction of that annoyance to the lowest possible minimum should be a matter of real concern and conscientious effort, not only for the comfort of the animals but for that of the milker as well.

The use of repellent sprays for this purpose has been at best a somewhat onerous and frequently disagreeable or only partially effective measure. Also, thus far, it has proven to be apparently the only feasible means of control on the majority of dairy farms.

Investigation of the status of the fly spray problem in Indiana has shown that the practice of spraying dairy cattle for protection against flies is quite general—in fact more so than might have been anticipated. But it has shown further that the program followed has been extremely haphazard, uncertain, and lacking a scientific basis.

The choice of a spray has been governed by the chance availability of some particular brand of proprietary material or by the glibness of a salesman, rather than by considerations based on comparative effectiveness, cost and practicableness.

It was in the hope of being able to acquire information upon which might be based intelligent recommendations that the writer was assigned the task of conducting the tests whose results are reported herewith.

The experiments were begun in the summer of 1924, and were that season carried on among nine dairy herds located in northern Indiana. They were continued in 1925 in ten herds of Hamilton County, central Indiana. The plan followed was to provide the owner or manager of each herd with one or more kinds of fly spray materials, and arrange with him to apply such spray according to directions furnished. The effort in other words was to secure the application of these sprays under practical farm conditions and according to methods which would ordinarily be employed by the average farmer, with a somewhat added care and thoroughness induced by instruction and supervision by experimental agencies.

Only the milch cows were sprayed, the number in each herd ranging from seven to twenty-five. In some herds in 1924 one material alone was used: some were divided, two materials being used, one on each division; and in one herd three materials were employed. In 1925 only one spray in each herd was tested.

The sprays tested were selected on the basis of a representative range of type and a promising degree of effectiveness as indicated by recommendations from various sources. The formulae are indicated as follows:

Home Mixed Sprays

Spray No. 1.

Chlorozone (A stock dip manufactured by the Great Western Oil Co.)	½	gallon
Oil of tar	2	gallons
Kerosene	2½	gallons

Spray No. 2.

Coal tar dip	4½	quarts
Fish oil (dark)	4½	quarts
Whale oil (light)	3	quarts
Oil of tar	1½	quarts
Kerosene	3	quarts
Laundry soap	3	bars
Water to make	30	gallons

Spray No. 3.

Fish oil	2	quarts
Oil of tar	1	quart
Crude carbolic acid	⅛	ounce

Spray No. 4.

Powdered resin	3	pounds
dissolved in		
Hot water	3	gallons
softened by . . .		
Sal soda	½	pound
Laundry soap	3	pounds
Kerosene	1	quart
Fish oil	1	quart

Spray No. 5.

Kerosene emulsion 10%

Spray No. 6.

Used crank case oil	1	gallon
Oil of tar	1	pint

Spray No. 7.

Used crank case oil	1	gallon
Chlorozone	1	pint

Proprietary Sprays

Spray No. 8.

Bovinol—a clear, colorless and odorless oil spray manufactured by the Standard Oil Co.

Spray No. 9.

Cow Ease—a commercial coal tar preparation.

Spray No. 10.

Standard Oil Co., Formula No. 3379. (Similar to Bovinol).

A uniform method of applying all sprays once per day immediately following the morning milking was employed in nearly every herd, though there were several exceptions where the operator felt it necessary to make an evening application during a part or all of the season or in the case of two herds where it was desired to test the effects of twice daily applications versus once daily applications for certain materials.

Results were checked by reference to testimony of the operators concerning the various factors involved and by occasional corroborative observation by the writer.

Sprays tested in 1924 were Nos. 1, 2, 3, 4, 8, and 9. Those tested in 1925 were Nos. 1, 3, 5, 6, 7, 8, and 10.

Comparative Cost

An exact mathematical average reduced to a common basis of the cost of materials for spraying ten cows for a period of 90 days, reveals the following figures:

Spray No. 2	$13.50
Spray No. 10	7.20
Spray No. 8	6.79
Spray No. 3	5.26
Spray No. 9	3.91
Spray No. 1	2.47
Spray No. 7	.90
Spray No. 6	.90
Spray No. 4	.85
Spray No. 5	.17

Comparative Effectiveness

Summarizing the results and deductions from all observations throughout the two season's tests; taking into consideration varying conditions and amounts of spray used; and from this reducing conclusions to a common basis of reasonable, optimum intensity, regularity, care and thoroughness of application, it is felt that in terms of protective power, both immediate and permanent, the sprays tested may be rated as follows:

Nos. 1, 3, 6, and 7, are equally and most permanently efficient in protecting cows from blood-sucking fly attack.

No. 2 was equally effective with Nos. 1, 3, 6, and 7, but required much heavier and more costly application to achieve the same results.

Nos. 9 and 4 were only slightly less effective than the above.

No. 5 gave a high degree of protection practically equal to the most effective sprays, during the early part of the season. Later, however,

apparently insurmountable difficulties arose in securing an emulsion which would remain stable and effective for a sufficient length of time to prove practicable. Over the greatest part of the season kerosene emulsion (No. 5) gave relatively poor results.

No. 8 showed better results in 1925 experiments than in those of 1924. Its value is dependent primarily on the amount used. Where used in quantities comparable with the most effective odorous repellents it shows a lower degree of immediate and permanent protective power. Where used very liberally, with a strongly ascending cost, Bovinol showed fairly good protective effect.

The one test where spray No. 10 was employed was one in which the material was used rather more liberally than would probably be the case ordinarily with odorous sprays and the results obtained were quite satisfactory. Indeed, used at the rate indicated, it gave a marked degree of protection, lasting well for nearly an entire day at a time. However it is relatively expensive, due primarily to original cost rather than to necessity for excessive application.

Practicableness

This factor includes such items as ease of preparation and application, and effect on man and animals about the stable and in the field.

Nos. 8 and 10 possess superior qualities in this respect from every standpoint.

No. 9 requires no preparation, is easy to apply, and no complaint was heard concerning any objectionable effect on man or animal other than some staining of the coat.

No. 1 is simple and easy to mix, easily sprayed, ordinarily unobjectionable as to odor about the stable, and does not color the hair noticeably unless used in excessive quantity.

No. 3 is easily prepared, but occasionally gives some trouble in application on account of thickness. This was not the cause of great complaint, however. It ranks with No. 1 in respect to effect on man and animals.

No. 2 contains a wholly unnecessarily large number of different ingredients, some of which are not always readily available and making preparation difficult.

No. 4 is hard to prepare and gave considerable trouble in application by clogging.

The preparation of No. 5 is too troublesome for the average farmer, and the difficulty of securing a stable and effective emulsion for this purpose has already been emphasized.

Nos. 6 and 7 are simple and easy to prepare, easy, safe and unobjectionable in application, absolutely non-injurious to both operator and the herd, while the base material, used crank case oil, is often easily available on the farm itself or at a nearby garage or filling station.

No. 7, containing chlorozone, is open to some objection on account of the possibility that chlorozone might not always be readily available.

Additional Conclusions

1. Cows regularly and carefully sprayed with the most effective odorous repellents exhibited a high degree of protection from blood-sucking fly attack, especially as compared with unsprayed animals. Sprayed herds were noticeably quieter at pasture and in the barn at milking time, strikingly more contented, fed more peaceably and exhibited far less nervousness than unsprayed herds.

2. The lasting effect of these sprays exceeded expectations. In most cases one application per day was reported to effectively protect the cows, though a few of the experimentors felt it desirable to apply an evening spray just before milking to insure perfect quiet at that time.

3. Herds in which the heaviest and most complete spraying was done were noticeably freer of flies and the repellent effects lasted longer than on herds where the spraying was light. However, it was clearly demonstrated that a complete, careful but moderately liberal application was practically as effective as the heaviest applications. In other words, it is possible to spray so heavily as to go beyond the limits of satisfactory control without any added gain, as well as to drop beneath an optimum application and secure inferior results.

Spray No. 6, for example, used at the rate of one-half gallon per week on a herd of ten cows, gave very nearly optimum results in terms of cost, effectiveness and practicableness.

This rate may be said to represent that normally required for most of the more effective odorous repellents to produce optimum results, although it will fluctuate considerably with varying conditions, such as weather and fly abundance.

4. In the case of the effective odorous sprays, it was observed that the repellent influence of the spray was extended to unsprayed animals in the herd.

5. A study of the records indicates that in herds carefully sprayed with the most effective odorous repellents, there was a progressive and consistently cumulative reduction in fly infestation and nervous response on the part of the animals as the season advanced.

6. Where one application per day is employed, the most satisfactory and effective time for it proved to be immediately following the morning milking. In periods of especially heavy fly abundance and severity of attack very probably it may be necessary to make a light evening application. Daily applications are necessary in most cases, though there were occasions during cool weather when the daily spray was omitted for as much as two or three days at a time without resulting in noticeable recurrence of fly attack.

Species of Flies and Reaction to Sprays

The horn fly (*Haematobia irritans* L.) was much the most abundant species observed on unsprayed cattle throughout the two seasons' work. It was present during the entire season, being more abundant and troublesome in 1925 than in 1924.

The stable fly (*Stomoxys calcitrans* L.) was closely second to the horn fly in importance both in 1924 and 1925. In fact certain herds suffered more from stable fly attack than from horn fly attack, not because of greater numbers of the former but because of greater persistence and severity of attack.

Repellent sprays are less effective in protecting cows from stable fly attack than from horn fly attack. Indeed it was a frequent experience to observe well sprayed herds completely free from the presence of even a single horn fly, but even on such animals at least a few stable flies were observed and caused some annoyance.

This appears to be due partly to the fact that the stable fly is more resistant to the effects of repellent sprays and partly to the fact that it habitually attacks the legs and underparts where the spray is likely to become brushed and washed off as the animals move through dew soaked woods and fields.

Horse flies (Tabanidae) were of no importance, practically none having been observed attacking cattle.

Two herds were observed early in 1924 to be infested somewhat by mosquitoes. One herd being sprayed with Cow Ease and Bovinol, was rather heavily infested and the mosquitoes were feeding. The other herd, though in a pasture thickly infested by mosquitoes was not being attacked to any extent. This herd was being heavily sprayed with formula Nos. 2 and 3.

Spray Appliances

The type of sprayer used in the above tests was in nearly every case of the cheap hand atomizer type. While the inexpensiveness and easy

availability of this type of apparatus appeals to many farmers, those few men who used sprayers of the compressed air type felt fully recompensed for the additional original outlay by the greater ease of operation, more effective uniformity of application, and reduction of labor and time secured by the use of the better type of machine.

Finally, it may be said that every spray tested showed some virtue. Some may be eliminated because of obvious defects in form of excessive cost, lack of maximum protective power, difficulty of availability, preparation or application.

While such sprays as No. 10 for example show good protective power, great practicableness and special fitness for use on animals which it is desired to protect absolutely from any coloring of the hair and while such as No. 1 presents ideal qualities in respect to protective virtue, simplicity and ease of preparation and application and a satisfactory degree of practicableness from nearly every other standpoint; from a consideration of every factor involved, cost, effectiveness, safety and practicableness, it is felt that spray No. 6 (used crank case oil and oil of tar) offers at present the most satisfactory repellent fly spray tested under practical dairy conditions.

FIELD TESTS WITH REPELLENTS FOR THE SCREW WORM FLY, *COCHLIOMYIA MACELLARIA* FAB., UPON DOMESTIC ANIMALS

By E. W. Laake, D. C. Parman, and F. C. Bishopp, *U. S. Bureau of Entomology* and R. C. Roark, *U. S. Bureau of Chemistry*

Abstract

Results are presented of tests of a number of promising repellents when used under range conditions for the protection of cattle, sheep, goats and other animals against the screw worm fly *Cochliomyia macellaria*. In these experiments the worms were first killed with benzol and the repellents applied every other day until the wounds were healed. Considering effectiveness and various other factors, pine tar oil with specific gravity of 1.065 ranks first among the materials tested. The 18 repellent mixtures used in these experiments were selected as being the most effective of several hundred, as determined by extensive laboratory tests.

Since 1915 the Bureau of Entomology has been carrying on experiments with repellents for the screw worm fly (*Cochliomyia macellaria* Fab.) and other meat breeding flies. A progress report covering the work done up to the end of the season of 1922 has been published (Jour. Econ. Ent., vol. 16, pp. 222–224, 1923), and a summary of the work done during 1923–24 has also appeared (Jour. Econ. Ent., vol. 18, pp. 776–778, 1925).

The present paper gives a summary of the work done during the summers of 1924 and 1925 in treating screw worm cases on goats, sheep, cattle and other domestic animals on ranges in southwest Texas.

A number of the materials which were most promising as repellents as determined by applying them to meat in jars were used on animals which were infested with screw worms under ranch conditions.

Eighteen repellent mixtures were tested during 1924 and 1925 upon 564 animals, consisting of 332 goats, 78 sheep, 115 cattle, 28 horses, 5 hogs and 6 dogs.

The method of treatment was as follows: Benzol (previously reported as an effective larvicide, Jour. Agric. Res., vol. 31, pp. 885–888, 1925) was poured over the fly eggs and larvae in the wool or hair and in the wounds of infested animals. Usually the wounds were plugged for a few minutes with wads of cotton saturated with benzol in order to permit the vapor to reach and kill the larvae which were often deep in the wounds. The dead larvae and eggs were then removed as completely as possible and a repellent swabbed over the wound by hand. Enough repellent was used to thoroughly cover the wound and adjacent surface. Each animal was carefully numbered, either by paint on the horns or hair, or by means of a tag fastened around the neck or horns. All treated animals were separated from the large herds and kept in small pens or traps where they could be examined easily. The animals were examined regularly every other day, except Sundays, and were kept under observation until their wounds had entirely healed. No animal which was discharged as cured was later found to be reinfested at the site of the healed wound.

The following data were recorded for each animal, or for each wound in those cases where one animal had two or more distinct wounds: Sex and age of animal; general nature of wound (such as superficial or deep), location and size; nature of previous treatment for worms; general condition of the animal, whether infested with eggs or living larvae at the time of first inspection; number of times each wound was found reinfested, number of times each was treated with a larvicide or repellent; and the number of days required for each wound to heal.

On account of the wide variation in the size and nature of the wounds, such as castrations, brand marks, boils, broken horns, bites, wire cuts, etc., we have thought it inadvisable to judge the effectiveness of the different wound dressings by the time required for the wounds to heal. We believe that a consideration of the number of times a wound was reinfested, after the first application of the repellent under test affords a better index of the real value of a material as a fly repellent.

One of the materials tested, chloroacetone in combination with pine tar oil, was tried in only a few cases, because it was soon discovered that this treatment caused severe irritation of the tissues with which it came in contact. Chloroacetone is a good fly repellent, but in contact with an aqueous medium (blood and serum) it is partially hydrolyzed, forming hydrochloric acid, which is very injurious to animal tissue. None of the other materials tested injured the animal tissues or acted as a local or systemic poison. Furthermore, most of the materials tested have some antiseptic properties and a few of them, furfural and chloropicrin at least, are strongly antiseptic.

Out of the 18 repellent mixtures tested, seven were tried upon too few animals of any one species for an accurate estimation of their efficiency, and one of these, as mentioned above, was found to be injurious and was soon discontinued. With each of the eleven other repellent mixtures tested, from seven to eighty-seven wounds were treated on from one to three species of animals.

The number of wounds upon horses, dogs and hogs which were treated in these experiments was too small for an accurate estimation of the efficacy of any of the repellent mixtures for these three species of animals. No animals that died or escaped before the wounds had healed are included in this report.

In the table below is shown the average number of reinfestations for goats, sheep and cattle with the repellent mixtures arranged in order of their efficacy for each species of animal.

Unfortunately it was not found feasible to leave for checks untreated animals, since the injury to untreated animals is so severe that very often death will ensue. However, the results both as to protection of the wounds from flies and rapidity of healing were considered very satisfactory by all of the stockmen with whom the cooperative tests were carried out. These men averred that the repellent value of the various materials was higher than that of any mixtures previously tried by them. It should be borne in mind in considering the results as presented in the table that all of the mixtures used were excellent repellents.

In view of the cheapness, ready availability, non-toxicity to animals and the excellent adhesiveness of pine tar oil, none of the mixtures so far tested equals it when cost is taken into consideration. The market prices of these materials at the present time (December 1, 1925) are as follows: Pine tar oil, sp. gr. 1.065, 35c per gallon in 5 gallon lots. Beta-naphthyl ethyl ether, $22.70 per pound. Anise oil, star, $1.20 per pound in gallon lots. Lubricating oil (automobile motor oil), sp. gr.

0.930, Saybolt viscosity at 104° F. 495, manufactured from a mixture of crude oils of different bases, $1.00 per gallon in gallon lots. Furfural, 23c per pound in 500 pound lots. Chloropicrin, $1.00 per pound.

TABLE 1. REPELLENT MIXTURES TESTED AND THE NUMBER OF REINFESTATIONS PER WOUND ON GOATS, SHEEP AND CATTLE

Repellent Mixture	Number of wounds treated	Reinfestations Total number	Reinfestations Average number per wound[1]
GOATS			
Pine tar oil (95 vols) plus Beta-naphthyl ethyl ether (5 vols)	12	2	0.2
Pine tar oil (88 vols) plus lubricating oil (10 vols) plus star anise oil (2 vols)	26	11	0.4
Lubricating oil (95 vols) plus chloropicrin (5 vols)	14	7	0.5
Pine tar oil (80 vols) plus lubricating oil (17.5 vols) plus chloropicrin (2.5 vols)	13	8	0.6
Pine tar oil	87	67	0.8
Pine tar oil (75 vols) plus furfural (25 vols)	18	14	0.8
Pine tar oil (74.75 vols) plus lubricating oil (24.25 vols) plus chloropicrin (1 vol)	17	17	1.0
Pine tar oil (99 vols) plus chloropicrin (1 vol)	27	31	1.2
Pine tar oil (90 vols) plus furfural (10 vols)	20	24	1.2
Lubricating oil (99 vols) plus chloropicrin (1 vol)	21	27	1.3
Pine tar oil (87.5 vols) plus furfural (12.5 vols)	10	20	2.0
SHEEP			
Pine tar oil (99 vols) plus chloropicrin (1 vol)	12	11	0.9
Pine tar oil	7	11	1.6
Pine tar oil (74.75 vols) plus lubricating oil (24.25 vols) plus chloropicrin (1 vol)	7	17	2.4
CATTLE			
Pine tar oil	24	23	1.0
Pine tar oil (95 vols) plus Beta-naphthyl ethyl ether (5 vols)	9	9	1.0
Pine tar oil (87.5 vols) plus furfural (12.5 vols)	8	9	1.1
Pine tar oil (75 vols) plus furfural (25 vols)	18	30	1.7
Pine tar oil (99 vols) plus chloropicrin (1 vol)	13	24	1.9
Pine tar oil (74.75 vols) plus lubricating oil (24.25 vols) plus chloropicrin (1 vol)	7	19	2.7

[1]Some of the wounds were reinfested more than once.

THREE INJURIOUS INSECTS RECENTLY INTRODUCED INTO CONNECTICUT

By W. E. Britton, State Entomologist, *New Haven, Conn.*

Abstract

The Asiatic beetle, *Anomala orientalis* Waterhouse, has caused considerable injury to lawns by the grubs eating the roots of grass, some being noticed in the fall of 1922. In each of the seasons of 1923, 1924 and 1925, the injury had been observed but was not very conspicuous in 1925 until late summer. During August, September and October, there were many complaints and reports from an area of approximately one-fourth of a square mile in extent. The matter was again reported to the Bureau of Entomology and the Federal Horticultural Board, with a request that they send some one to look over the situation. Later Mr. L. B. Smith submitted a report recommending that an effort be made to eradicate this pest; for should it spread southward it might cause serious injury to various crops; that the entire area not covered by buildings or pavements, be treated with carbon disulphide next spring to kill the grubs. Plans are therefore being made to procure the necessary funds, and to carry out Mr. Smith's recommendations.

The mines of the Imported Birch Leaf-Miner were first noticed in Connecticut in 1923, and the following year the adult was reared and found to be a sawfly, *Fenusa pumila* Klug, from Europe. Observations made in 1925 show that there were three complete generations and a partial fourth. Eggs are laid in the tender terminal leaves, and hatch in about ten days. The larval period requires an average of 11 or 12 days, and the winter is probably passed in the pupa stage.

This insect is now distributed throughout southern New England, southeastern New York, and in Vermont as far north as the vicinity of Rutland. Apparently it prefers the gray birch, *Betula populifolia*, but also attacks the white or canoe birch and the European white birch, including the cut-leaf form. Most of the mines are on young sprouts or seedlings, though in a few cases they have been observed on larger trees.

On September 8, 1925, stems of *Rosa rugosa* were received from Darien exhibiting the peculiar swellings or galls such as have been figured by Weiss as occurring in New Jersey and caused by *Agrilus viridis* var. *fagi* Ratz., a species from Europe. On October 15, stems of *Rosa hugonis* were received from Norwalk with similar galls. Norwalk and Darien are adjoining towns. The adults have not been reared in Connecticut, but it is characteristic *Agrilus* work.

A Beetle from the Orient

A few specimens of the Asiatic beetle, *Anomala orientalis* Waterhouse, were collected at New Haven, on July 16 and 21, 1920, by Messrs. M. P. Zappe and B. H. Walden, Assistant Entomologists of the Station. The beetles were pinned up and put away with other material to be examined later, but on account of a pressure of work, the later examination was deferred. On July 26, 1921, a few more specimens were collected in the same locality by Messrs. Zappe and Walden. These beetles were at once recognized as belonging to the genus *Anomala*, but were different

from any species in the Station collection, or that any of us had ever seen. In the fall of 1921, specimens were sent to Mr. Charles Schaeffer of the Brooklyn, N. Y. Museum, who at that time was studying the American species of *Anomala*. Mr. Schaeffer was unable to identify the species, but thought that it was not a native and stated that it had probably been introduced from some other country. He afterwards sent it with other material to the British Museum of Natural History where in due time it was identified by Mr. Arrow as *Anomala orientalis* from Japan. I have recently been informed that this insect is a native of the Philippines. Mr. Arrow referred to its record as a destructive pest of sugar cane in Hawaii and stated that if it should obtain a foothold in the United States, it might possibly prove to be as injurious as the Japanese beetle in New Jersey.

This report came to me on May 17, 1922, and a few days later the information was sent to the Bureau of Entomology and published in the Insect Pest Survey Bulletin, and the facts were placed before the Federal Horticultural Board.

The exact locality where these beetles were taken was on the former site of a nursery, but now covered with residences, in the Westville section of New Haven, just south of Edgewood Avenue. The best probable explanation of the introduction is that it was brought in balls of earth on the roots of nursery stock, as this nursery imported plants from Japan prior to 1917, when the Federal Horticultural Board wisely prohibited all further importations of plants unless the soil had been removed from the roots.

Late in the fall of 1922, a friend called my attention to his lawn where grubs had eaten the grass roots forming a dead area perhaps four by eight feet. I supposed that they were common white grubs, the larvae of May or June beetles, but on examining them, they seemed smaller and more active. I gathered twenty-five or thirty, placed them in a small tin box with a little soil and took them to the laboratory. They nipped each other with their mandibles and all died. Soon I heard of other lawns that were being injured by grubs, and I began to wonder if these grubs might not be the larvae of *Anomala orientalis*. In the spring of 1923, more grubs were collected and at once separated, only a few being placed in each box, with plenty of soil, so that they could not injure each other. On July 24, 1923, some adults emerged and proved to be identical with the beetles collected in 1920 and 1921.

No very careful studies have been made of the life history and habits of this insect in New Haven. Adults appear in July and the females lay

eggs in the soil, which hatch in a few days and the young grubs feed upon the grass roots within an inch of the surface. They are perhaps half grown when late in October on the approach of cold weather, they go deeper into the soil for protection from the cold, and return to the surface again in spring. They resume feeding and reach larval maturity in June and pupate in cells in the soil. Apparently there is only one generation each year though a few of the larvae fail to transform the first year and run over into the second season. The adults are found in the turf or crawling upon the stems of grass or weeds, and apparently fly or feed very little. If this is true, the natural spread is much less than would be the case were it a strong flier. There is much danger in moving plants or rubbish, or grading lawns that some of the infested soil may be carried to some other locality and new colonies started. Property owners have been warned regarding this danger. I fear that this may already have occurred, though all reports which have come to my attention as well as all observations up to this time indicate that the pest is centered on an area of about one-fourth of a square mile.

The Hymenopterous parasite, *Scolia manilae* Ashm., which was so effective in subduing this pest in Hawaii, has already been brought to New Jersey as a possible parasite of the Japanese beetle, but does not survive the winter there.

The first half of 1925, very little injury could be seen and I reported to that effect at the summer field meeting at Washington, D. C., July 29, but during August and September many reports were received and finally the injury became more conspicuous than it has been during the three years since first noticed.

This was reported to the Bureau of Entomology and the Federal Horticultural Board with a request that some one come to Connecticut and look into the situation. On October 29, Messrs. Loren B. Smith, B. R. Leach and J. P. Johnson of the Japanese Beetle Laboratory, Riverton, N. J., were sent to New Haven, by the Bureau of Entomology and in company with Director W. L. Slate, Jr., M. P. Zappe and myself, the area was inspected. A few days afterward, Mr. Smith submitted a report recommending that an attempt be made to eradicate this pest, the work to be done co-operatively by the Bureau of Entomology and the State of Connecticut. The estimated cost of treating the entire area is $25,000.00. He considers that *Anomala orientalis* may prove to be a serious pest of various plants and crops if it should spread very far to the southward.

Measures have already been taken to raise funds, and other plans

will be made to begin the treatment with carbon disulphide emulsion as soon as the beetles resume their feeding near the surface next spring.

A Birch Sawfly Leaf-Miner From Europe

During the summer of 1923 in several localities in Connecticut it was noticed that the terminal leaves of the sprouts of gray birch, *Betula populifolia*, had been injured by leaf-miners. The mines were of the blotch type and in some instances involved the entire leaf. In other cases one side, the base, or the tip only would be mined. The work was observed at Rainbow in July, during the summer meeting of the Northeastern Entomologists, and some twigs were gathered and put in one of the automobiles and forgotten.

In 1924, at my request, Mr. R. B. Friend, Assistant Entomologist of the Station, who was studying the birch leaf skeletonizer and visiting birch plantations, gathered material on July 21 and placed it in the insectary. On August 6, he obtained several small sawflies, including both sexes. Specimens were sent to Mr. S. A. Rohwer of the U. S. National Museum, who identified them as a European species, *Fenusa pumila* Klug, which prior to that time was not known to occur in this country. Brief notes were published in the Journal of Economic Entomology, Vol. 17, page 601, October 1924, and in the Report of the Connecticut Agricultural Experiment Station for 1924, page 340, the latter showing on Plate XXXV, a, the appearance of the mined leaves.

In 1925, mines were conspicuous as soon as the leaves were about full size, and on July 2 and July 4, adults were very abundant on the leaves at Mount Carmel, mating and laying eggs. The leaves had already been mined by one brood of larvae. On July 19, no adults were seen at Mount Carmel, though larvae could be seen in the mines, which were quite large, and in some cases there were several larvae in one leaf and their mines coalesced and covered the whole leaf.

On August 1, the adults were again abundant, and some were collected. Again, a month later (September 1) adults were present, though not as abundant as on July 1 and August 1. Thus there are three full broods and probably a partial fourth brood, perhaps depending upon the weather. Mines are made in the tender leaves and are seldom found in hard and fully matured leaves. On old leaves, the adults do not seem to oviposit and if eggs were laid there, the young larvae probably could not feed upon the hardened tissues. Late in the season there are few new leaves and consequently the insect cannot obtain food and multiply as rapidly as is the case earlier in the season.

Mr. Friend observed one larva at work in a leaf having an area of 710

square mm. At the end of the larval period, the mine had an area of 180 square mm., or 25.4 per cent of the total area of the leaf.

Though for the most part this leaf-miner is found on gray birch, and chiefly on the sprouts or young seedlings, it is not wholly confined to this host. A seedling of paper birch in my garden was mined in about the same manner as gray birch, yet there was no evidence of it on the large paper birch trees close by. Dr. Felt tells me that he has observed mined leaves on gray birch at least fifteen feet from the ground and Mr. Friend has also noticed some mined leaves ten to fifteen feet above the ground. On July 15, some mined leaves of European white birch were received from the Barnes Brothers Nursery Company, Yalesville, Conn., but I have no data regarding the size of the trees. No member of our department staff has observed this miner in the leaves of black birch, *Betula lenta* or in yellow birch, *Betula lutea*. There is a possibility that it may seriously injure the appearance of cut-leaf and other shade and ornamental birches, and if so, some remedy will be demanded.

Mr. Friend has made observations on the length of the larval period of this insect, which varies from six to fifteen days, but in a large proportion of the records, eleven or twelve days is the period, and I think may be taken as the average. The eggs hatch in about ten days, though we have few data.

When fully grown, the larvae leave the mines and pupate in cells in the soil. No data have been gathered on the length of the pupal period, though probably as with other sawflies, larvae which enter the ground late in the season do not pupate until the following spring.

The adults are black and too small to be very conspicuous.

Fenusa pumila Klug is known to occur throughout Connecticut, Rhode Island, Massachusetts, eastern New York, and in Vermont as far north as the vicinity of Rutland.

An Imported Beetle Forming Galls on Rose

On September 8, 1925, some stems of *Rosa rugosa* were received from Darien, Conn., exhibiting peculiar swellings or galls resembling those figured by H. B. Weiss[1] as occurring in New Jersey and caused by *Agrilus viridis* var. *fagi* Ratz., a species from Europe. On October 15, stems of *Rosa hugonis* were received from Norwalk with similar galls. Norwalk and Darien are adjoining towns. Though there has not been time to rear the adults in Connecticut, the galls are quite characteristic

[1]New Jersey State Department of Agriculture, Bureau of Statistics and Inspection, Circular No. 36, page 9, 1921; Circular No. 48, page 13, 1922.

of *Agrilus*, several species of which make similar galls on other shrubs and trees, and resemble so closely the injury to rose figured and described in the publications from New Jersey that I have no hesitation in ascribing it tentatively to this species.

AN INSECT OLFACTOMETER

By N. E. McIndoo, Ph.D., *Entomologist, Fruit Insect Investigations, Bureau of Entomology, United States Department of Agriculture, Washington, D. C.*

ABSTRACT

Briefly stated, the insect olfactometer consists of a specially constructed Y-tube through which insects pass from a dark chamber, being attracted by a light suspended near the free ends of the forks of this tube. The dark chamber is attached to the base of the Y-tube, while a suction apparatus to draw odors through the forks is attached at the point where the base and forks unite. The principle involved is to attract the insects equally toward the entrances of the forks by the light stimulus, but when ready to enter these forks they are influenced unequally by the odors drawn through the forks, one fork serving as an attractive or repellent side and the other fork as the control side. The whole apparatus is so constructed and manipulated that the interfering factors are practically controlled, leaving only the olfactory responses to be recorded.

It seems that so far as the insects are concerned, the key to success in work of this kind depends upon the proper physiological state of the species which is being tested. The proper state perhaps includes many factors, but particularly the proper age and sexual condition, and a hungry condition when food odors are being used.

In this investigation it was shown by a large series of experiments that potato beetles can be induced to respond to their food odors by subjecting them to the odors from water extracts and steam distillates of their host plants, and it was further shown by another large series of experiments that these insects can be induced to respond to the emanations from their living host plants, giving experimental proof for the first time that plants attract insects by emitting odors.

Emanations, drawn through the apparatus from living potato plants, could not be detected by the writer, but in every one of the 24 experiments conducted the potato beetles gave attractive responses, the highest percentage being 76.7 per cent.

After aerating the steam distillates of potato foliage, potato tubers, horsenettle, henbane, and tomato plants for some time, the odors from all of these distillates became attractive to insects, and the writer could detect a common odor among them. This odor closely resembled that from boiling potatoes or from the juice of freshly cut potatoes, and might be called a potato odor. Since all these plants belong to the potato family (Solanaceæ), it would be interesting to know whether they possess a particular constituent or constituents which emit a common odor, as is indicated by the responses of the beetles and by the writer's nose. If so, it is suggested that the chemist tell us what they are, so that we may use them in poisoned baits or in traps, thereby perhaps reducing the cost of controlling potato beetles which must now be done by dusting and spraying the potato plants.

Introduction

In the spring of 1924 Dr. A. L. Quaintance, Associate Chief of the Bureau of Entomology, suggested that the writer make a study of repellents and attrahents (commonly called "attractants"). During the season of 1924 this work was conducted in Washington, D. C., at the Delta Boll Weevil Laboratory in Louisiana, and at the Japanese Beetle Laboratory, Riverton, N. J., but no conclusive results were obtained, although many ideas were gained, which served as a basis for the experiments on which this report is based.

It soon became evident that if the fundamentals of "attractants" and repellents were to be studied, special apparatus for measuring or recording the responses of insects to these substances must be developed. Accordingly, a crude apparatus was devised in the early stages of the investigation, which after many improvements, became the insect olfactometer mentioned in these pages. The original idea was to develop a piece of apparatus by which repellents and "attractants" might be quickly and accurately determined in the laboratory and then applied in the field, thus eliminating the time and expense which are necessarily involved in field work where the trial and error method of procedure are used. The apparatus so far developed falls short of the original idea, but may serve as a basis for something more practical.[1]

This paper embodies only the results obtained in Washington during the season of 1925, and the Colorado potato beetle has been used as a typical insect for this kind of work.

Description of the Insect Olfactometer

The name "olfactometer" means an olfactory meter or measuring apparatus, and the one described in this paper has been used to measure or record the responses of insects to "attractants" and repellents. The word has been borrowed from an apparatus, called an olfactometer, commonly found in psychological laboratories, and which was perfected by the Dutch physiologist, Zwaademaker (Die Physiologie des Geruchs. Leipzig, 1895). The principles involved in these two pieces of apparatus are entirely different. Barrows in 1907 (Jour. Exp. Zool., vol. 4, p. 515–537) seems to have been the first to use the principle adopted by the

[1]In trying to develop a satisfactory apparatus, the writer has been aided by ideas of numerous entomologists. He heartily thanks two persons in the Bureau of Chemistry, where through the kindness of Mr. C. C. McDonnell, the specially constructed Y-tubes on several occasions were made by Mr. W. B. Symonds, the glass blower. Particular acknowledgment is due Mr. Symonds for the care which he exercised in making these tubes accurate and symmetrical.

present writer. His apparatus was fairly satisfactory for use in attracting pomace flies to odorous substances, but for testing other insects the writer did not consider it suitable; therefore, using the same principle, a considerably different type of apparatus has been developed.

The most improved and the most satisfactory insect olfactometer yet made by the writer, consists of three essential parts—a specially constructed Y-tube (Fig. 27, *A*), a common suction apparatus (*E*), and a special electric light (*H*). The Y-tube is made of Pyrex glass tubing having an inside diameter of one-half inch and six openings instead of the usual three. The base or stem (*A*) of the Y is 2 inches long and has an upright constriction one-fourth inch wide where it joins the forks (A_2). The forks are 8 inches long, and instead of making an acute angle where they unite they are symmetrically curved. Arising perpendicularly 1.5 inches from the point where the forks and stem unite is the exit tube (A_3), and 1.5 inches in front of this tube arise two similar tubes, the entrance tubes (A_4), one from each fork. Just beneath the exit tube the Y-tube is slightly expanded, having an inside diameter of five-eighths inch instead of one-half inch as at all other points.

Two bottles (*B* and B_2), 4.5 inches tall and holding 100 cc., are connected with the Y-tube by means of two glass tubes (B_3), 10.5 inches long, and their entrance tubes (B_4) open directly to the outside air when both bottles contain liquids, but when one of these bottles is connected with a 1,000 cc. graduate (*C*), which serves as a chamber for living plants (C_2), the other entrance tube is exchanged for a much longer tube (C_3), and in turn the plant chamber communicates directly with the outside air by a much longer entrance tube (C_4).

The stem of the Y-tube is connected with a dark bottle (*D*), 4.5 inches tall and holding 180 cc., which serves well as a dark chamber for insects because it is securely wrapped with black carbon paper.

The suction apparatus consists of two 5-gallon bottles (*E* and E_2) and two rubber siphons, one of which (E_3) connects with the exit tube (A_3) of the Y-tube and the other (E_4), being 4 feet long, connects with the 5-gallon bottle (E_2), which stands on the floor.

The rubber siphons and their glass-tubing connections have an inside diameter of three-sixteenths inch, while the other small glass tubes (B_3, B_4, C_3, and C_4) have an inside diameter of three-thirty-seconds inch. The sizes of the rubber stoppers used are as follows: No. 0 in the three tubes A_3 and A_4 and in the ends of the forks; No. 5 in bottles *B* and B_2; No. 7 in bottle *D;* and No. 6 in bottle *E*. A very large cork stopper (perhaps No. 13), was soaked in paraffin and used in the plant chamber *C*.

Before attaching the dark bottle (*D*) and siphon (E_3), the Y-tube is inserted into a 5-inch cubic box (*F*) so that the stem (*A*) projects through the hole on the left side of the box, and the siphon through the hole on the top side of the box. The interior of the box is painted black and its open side faces directly toward the light, so that side lights and reflected rays are eliminated.

Most of this apparatus rests on a thick board (*G*), which together with the two bottles (*B* and B_2), rests on a table against a west window. When artificial light is used the shade of this window is pulled down, and the blue daylight bulb (*H*), labeled "Edison mazda 110V 75W," is suspended from above so that the filament in the bulb hangs about 4 inches from the ends of the forks at the same elevation as that of the Y-tube and midway between the forks if they were extended. When a record of the temperature between the forks is desired, a thermometer (*I*) is suspended from above so that the mercurial end hangs midway between the forks and about 6 inches from the light.

How the Insect Olfactometer was Operated

The principle involved, which makes such an apparatus applicable, is the fact than many insects are positively phototropic. In regard to this particular apparatus, only those insects which respond readily to lights are promising ones. Therefore, positive phototropism was used as the initial stimulus in order to induce the insects to respond to odor stimuli. The plan was to attract the insects from the dark bottle (Fig. 27, *D*) equally toward the entrances of the forks by the light stimulus, then when about ready to enter the forks they would orient themselves by the odors drawn through the forks, one fork serving as the attractive or repellent side and the other as the control side. After passing into the forks, the insects were to be held there by means of the light stimulus until the end of the test, when they are counted. Since the interfering factors were practically controlled, as stated in the following pages, the difference in the number of insects counted in the two forks at the end of a test was to be attributed to the presence of the odor stimuli.

One illustration will show that the insects passed in nearly equal numbers into the forks when both sides of the apparatus were practically identical. The apparatus was assembled as shown in Figure 27, with the box (*F*) also in position, and with the bottles (*B* and B_2) and the plant chamber (*C*) dry and empty. Fifty potato beetles were then put in the dark bottle, the electric light turned on, and the water run through the suction apparatus for fifteen minutes, when it was stopped with a clamp on the siphon (E_4). At the end of 15 minutes 17 beetles

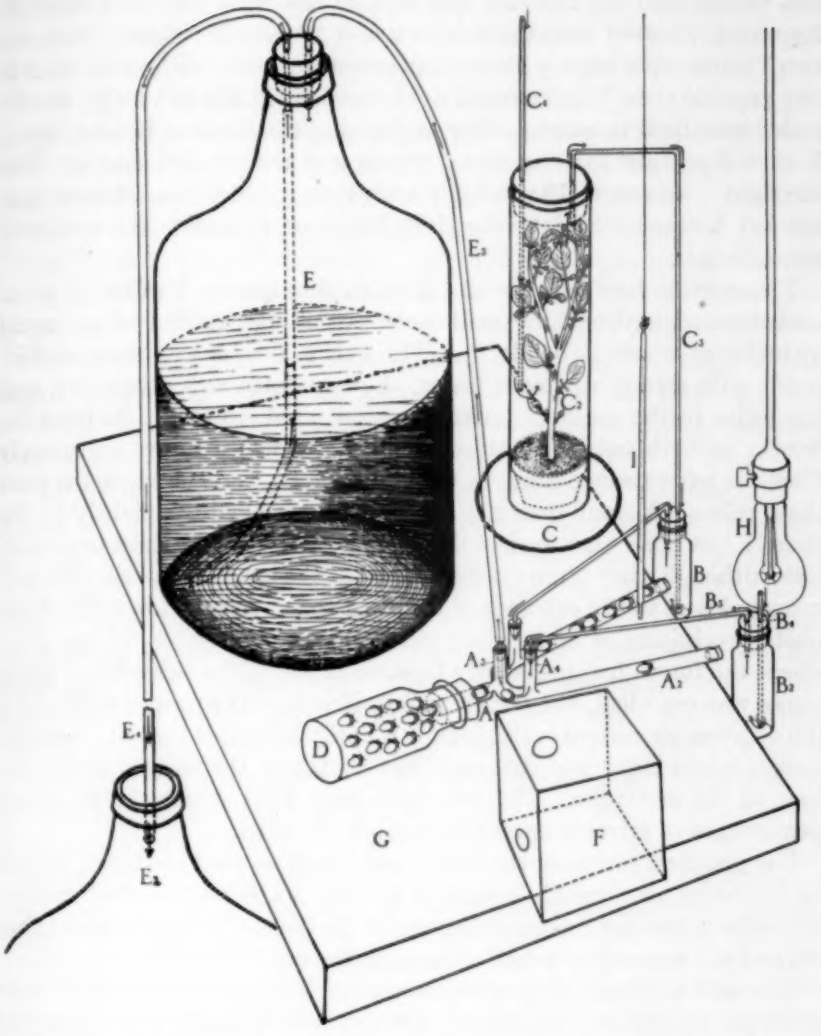

Fig. 27—The most improved insect olfactometer developed by the writer. *A*, stem of Y-tube; A_2, forks of Y-tube; A_1, exit tube of Y-tube; A_4, entrance tubes of Y-tube; *B*, bottle to hold odorous substance; B_2, bottle to hold control substance; B_3 and B_4, exit and entrance tubes of bottles *B* and B_2; *C*, plant chamber; C_2, living potato plant; C_3 and C_4, exit and entrance tubes of plant chamber; *D*, dark bottle to hold insects; *E* and E_2, 5-gallon bottles, the latter stands on floor; E_3 and E_4, siphons, the latter four feet long; *F*, 5-inch cubic box, through which Y-tube is inserted, to eliminate side lights etc., *G*, thick board; *H*, electric light; and *I*, thermometer.

had passed into the left fork and 20 into the right fork of Y-tube *A*. Repeated, 22 went into the left fork and 18 into the right. Since no two Y-tubes were exactly identical in structure, and in order to eliminate any possible error from unequal light reactions in the two forks, the Y-tubes were used in pairs. After exchanging the 5-gallon bottles, using Y-tube *B* and the same beetles, 20 went into the left fork and 23 into the right. Repeated, 19 went into each fork. Altogether, 78 went into the left forks and 80 into the right forks, or 49.4 and 50.6 per cent. respectively.

To ascertain how odorous air travelled through the Y-tube, 25 cc. of concentrated hydrochloric acid were put in bottle *B* and an equal quantity of water in bottle B_2. The entire Y-tube was then washed inside with strong ammonia water, the apparatus was assembled, and the water in the suction apparatus was started running. At once the liquids in both bottles bubbled equally and white fumes completely filled the left entrance tube A_4, the exit tube A_3, and the space between these tubes. A small quantity of the fumes backed up slightly in the stem *A*, but none went against the current of air into the right or control fork, although, they often circled around at the base of the exit tube and spread almost to the entrance of the right fork. After a few moments a white precipitate of ammonium chloride was perceptible on the glass where the fumes had previously been observed. The behavior of these fumes was not ideal, but served well to illustrate the route travelled by the odorous air currents; although it is easily imagined that at times the insects might have had difficulty in orientating themselves under the base of the exit tube. This condition may help to explain the small percentages of attractiveness many times recorded.

For practical purposes the entire apparatus seemed air-tight, judged by bubbling air through liquids in the bottles *B* and B_2, but mathematically it was not, because the sum of the areas of both entrance tubes (B_4 and C_4) was only one-half the area of the exit siphon (E_4).

The rate of the air currents through the Y-tube was very slow, only 2 feet per second or 1.4 miles per hour. These figures were obtained by calculating the rate of the water-flow through the siphon E_4 in connection with the 30-minute period required to empty one of the 5-gallon bottles. A current of air having an equal rate of speed would probably not be perceptible to us, but it was perceived by potato beetles, for more than 60 per cent of them went against the current in one fork when the entrance tube to the other fork was closed.

The humidity was kept practically the same in both currents of air by the use of equal quantities of liquids in the bottles *B* and B_2 when odors

from water extracts and steam distillates were being tested, and when the emanation from a living plant was being tested bottle B_2 was kept moist inside. This moisture about equalled the condensed water vapor emanated by the plant.

Daily weather records were kept, but outside climatic conditions were not interfering factors. When it was too dark to use daylight, artificial light was employed, in fact artificial light was mostly used. The temperature was seldom so low that the insects did not respond readily. When the electric light was used, it raised the temperature between the forks a few degrees above that in the laboratory, but at most times throughout the day it held the temperature near a constant degree.

The two forks were kept at the same elevation from the table so that gravity was not an interfering factor. The glass in the Y-tubes, being hard and slippery, was unnatural to the insects, but this condition existed in both forks.

The second factor not really controlled, although it was the same in both forks, was the fact that some of the insects were turned accidentally into the Y-tubes as a result of striking their heads against the curved glass just in front of them. The upright constriction in the stem caused them to pass straight forward into the currents of air, but some bumped their heads against the glass and were turned to one side before the odors had really oriented them. This is the second reason why higher percentages of attractiveness were not obtained, but a third and the most important factor which constantly tended to equalize the number of insects going into the two forks was the fact that many insects, perhaps all, passed through the Y-tubes too quickly, not allowing enough time for the odors to orient them.[2]

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[2]Since writing the above, the following criticisms have been offered: It is doubtful whether insects can readily discriminate as to the direction from whence the odor comes in the Y-tube, and orient themselves accordingly. This is true and probably explains why better attractive responses were not had. It is doubtful whether both forks can be illuminated equally. As conducted, this was not a serious interfering factor. Since the potato beetle is shown to be positively anemotropic to weak air currents, and since there is a difference in length of tubes B_4 and C_3, slight differences in regard to velocity and density of the air currents entering the forks might have existed; also there might have been slight differences in regard to humidity and temperature in these currents. Theoretically, these criticisms are well founded, but the slight differences enumerated, if they really existed, probably affected the results very little or not at all. However, in future studies they will be more seriously considered, and an effort will be made to simplify this apparatus, thereby eliminating the light factor, if possible, and all others that can be dispensed with.

Results Obtained With Potato Beetles

During the preliminary investigation in 1924 several species of insects were tested, but none seemed suitable to serve as a type for this kind of work. Since the Colorado potato beetle (*Leptinotarsa decemlineata* Say) is one of our most common economic insects and since it walks in a sluggish manner, it seemed promising as a favorable species to be used in chemotropic tests.

In this investigation it was first shown by a large series of experiments that potato beetles can be induced to respond to their food odors by subjecting them to the odors from water extracts and steam distillates of their host plants. After this point had been satisfactorily proved and sufficient experience gained in handling the beetles and the apparatus, it was further shown by another large series of experiments that these insects can also be induced to respond to the emanations from their living host plants. Having definitely settled these two points, the next step was to prepare a substance whose odors resembled those from the host plants and then to determine whether potato beetles could be attracted by the odors from this substance. Nothing was accomplished along this line; first, because the beetles then on hand had already been used too much; and, second, because the chemicals needed were not known to the writer.

Certain preliminary results and general observations will be stated first, and then will follow the other results obtained, some of which are also of a preliminary nature. The most important results have been tabulated (Tables 1 to 6) and also represented graphically (Figs. 28 to 33). These tables and figures are self-explanatory, except the following portions. The responses are called repellent and attractive, the repellent side of the Y-tube being the control fork when supposedly attractive substances were tested. These responses are divided by a neutral line of 50 per cent, which corresponds to the division between the forks. In the figures the attractive responses are represented above this line, and the repellent ones below it. As already stated, when both forks were used at the same time as controls, practically the same number of insects went into each fork, but in all other cases when the responses lie between 50 and 52 per cent on either side of the neutral line, the results should be considered neutral, thus allowing 2 per cent on either side of the line for probable errors. In the tables the number of insects used in each test includes both sexes, unless designated males (♂) or females (♀).

1. General Observations and Preliminary Results

At two different times adult potato beetles were collected in potato patches and were tried in the insect olfactometer, but they seemed no

more promising than the other insects previously tested. They responded readily to light, but not perceptibly to odors. They were really objectionable on account of their dirtiness.

The small potato patch near the laboratory became so heavily infested with larvæ that all the potato plants were totally eaten. Nevertheless, most of the largest larvæ pupated and later emerged from the ground as clean, shiny, and hungry adults, but since no food was at hand they began to crawl in all directions. Fortunately the writer saw them migrating and at once tested 50 of them. Since they responded to light and odors favorably and since they did not make the Y-tube dirty, 418 were collected on various days during the early part of June, 1925. Those collected each day were placed in a separate cage and were given water, but they had no food for several days, and consequently about one-half of them died before they could be thoroughly tested. When ready to be used, they were divided into sets of 50 individuals each and as long as they were under observation careful notes were kept.

Having found the key to success in handling this insect, it was decided to rear hundreds of other potato beetles during the second brood, and if possible, during the third brood. Accordingly, hundreds of large larvæ were collected in a potato patch in Maryland, then transferred to the writer's potato patch, and after a few more days of feeding, to a greenhouse, where they pupated and emerged as adults from July 17 to August 6. After emergence they were treated as already related, except that they were fed lightly when collected and thereafter periodically, the object being to keep them in a state of hunger and at the same time not to allow them to die for want of food. Several sets of beetles (all in each being practically the same age) were again secured, but not as many as were really needed. An attempt to rear a third brood was not a total failure, although too few eggs were laid to permit the rearing of large numbers of beetles.

In most of the experiments conducted it was found necessary first to scent the attractive side of the Y-tube before allowing the insects to pass through it, thus indicating that they are able to follow scented trails. This was done by drawing the odorous air through the apparatus usually for 15 minutes, but sometimes for 30 minutes, before the insects were put in the dark bottle.

The best results were usually obtained before the beetles had reached sexual maturity, for afterward unless the sexes were separated the results were confusing and often contradictory. This was owing chiefly to the fact that when sexually ripe the males ate less than the females, and their sexual urge was so strong that they constantly followed the

females, apparently paying no attention to food odors. Consequently, the beetles were tested repeatedly up to the mating period, and sometimes till they were worn out. Whenever a pair was caught in the act of mating they were separated, and from then on the sexes were kept apart and tested separately.

Using beetles from the first brood when the sexual urge was extremely strong, several experiments were conducted which indicated that these insects smell one another and can actually tell the opposite sex by smell. Repeated, using beetles from the second brood when the sexual urge was scarcely noticeable, the results obtained were confusing.

In conclusion under this heading, it seems that so far as the insects are concerned the key to success in work of this nature depends upon the proper physiological state of the species tested. The proper state includes perhaps many factors, but particularly the proper age and sexual condition, and a hungry condition when food odors are being used, as already mentioned.

2. Responses of Potato Beetles to Emanations From Living Potato Plants

Certain details, not yet mentioned, will explain how the apparatus was manipulated when emanations from living plants were tested. A living plant, just pulled from the ground with roots attached, was potted and placed in the plant chamber (Fig. 27, *C*), care being exercised not to bruise the leaves and stems. An equal quantity of soil from the same ground was put in the control bottle B_2. This soil was made more moist than that in which the plant was potted, the object being to have the water vapor emitted from the soil in this bottle equal the water vapor which emanated from both the soil and plant in the plant chamber. After the air currents had been drawn through the Y-tube for 15 or 30 minutes, 50 beetles were put in the dark bottle and then allowed to go toward the light. As usual, the beetles were tested twice in Y-tube A, and then after the plant chamber and bottle *B* were transferred to the right side and bottle B_2 to the left side, these same beetles or others were tested twice more in Y-tube B. The second experiment started immediately with Y-tube B and ended with Y-tube A; and the third experiment started with Y-tube A again, and so on. The results of each four individual tests were averaged and this average was considered the result of one experiment. These averages are given in Tables 1 to 6 and are represented as points (x) in the curves in figures 28 to 33; however, the first figure in each series of experiments and the first point in each curve represent the result of the first individual test, showing how the beetles

responded the very first time tested. Certain other detailed results are recorded in the tables, while a few others are not. The latter will be briefly discussed in their proper places.

The first four experiments were conducted with small thrifty potato plant A (Table 1 and Fig. 28, curve A). The highest percentage of attraction obtained as an average for 4 individual tests was 64.3 per cent.

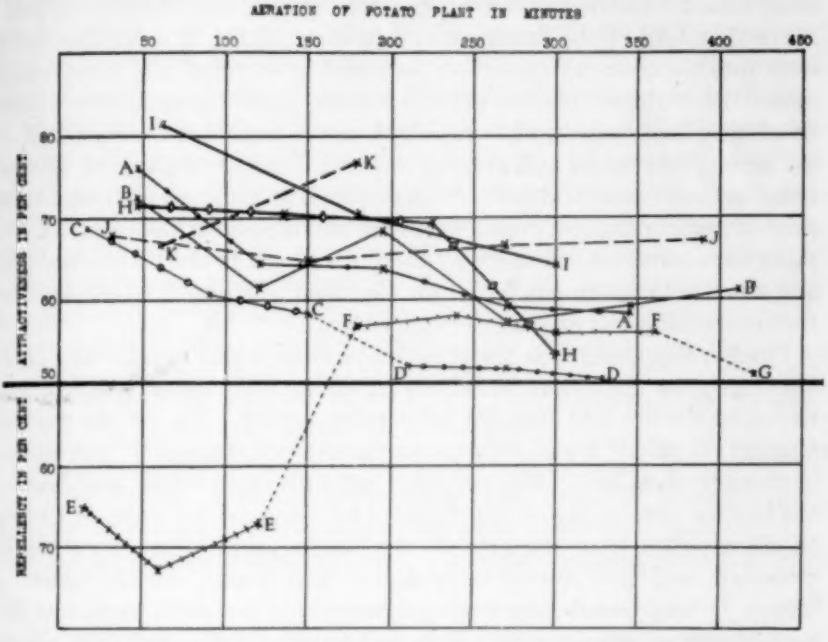

Fig. 28.[1]—Curves showing responses of potato beetles to emanations from living potato plants; *A*—*A*, small plant *A*; *B*—*B*, small plant *B*; *C*—*C*, smaller plant *C*; *D*—*D*, *control* for *C*—*C*, plant being removed; *E*—*E*, large plant *E*; *F*—*F*, one-half of plant *E*; point *G*, *control* for *F*—*F*, plant being removed; *H*—*H*, plant *H*, potted 9 days; *I*—*I*, plant *H*, potted 19 days; *J*—*J*, plant *J*, potted 3 days; and *K*—*K*, plant *K*, 3 branches in water.

These experiments were repeated 5 times using small potato plant B (curve B), and the highest percentage of attraction obtained was 68.4 per cent. Supposing that a smaller plant might give higher figures, plant C (curve C) was used twice, but it gave lower percentages of

[1]The writer has been asked to explain the many irregularities shown in most of the curves in figures 28 to 33. He has no explanation other than to say that the insects, plants, and apparatus used did not produce more satisfactory figures. When the subject is better understood, more satisfactory curves may be had. It has also been suggested that only one set of beetles should have been used in making a single curve; perhaps so, but insects soon become fatigued, thereby introducing other undesirable conditions.

attraction than usual. This smaller plant was then removed and 3 control experiments (curve D) were conducted without first airing the Y-tubes; consequently, the first two experiments gave about 2 per cent above the neutral or dividing line of 50 per cent, while the third gave only 0.3 per cent above. Next, supposing that a much larger plant would give the desired high percentages, large plant E (curve E) was twice tested. To the writer's surprise, the opposite results were obtained. More than half of the beetles tested in each of the 8 individual tests went into the control fork, called the repellent side in Table 1 and represented below the neutral line of 50 in Fig. 28. Since the emanations from this large plant were strongly repellent, it was imagined that one-half of the same plant might still give the desired high percentages of attractiveness; but the responses (curve F) did not so indicate, although they were attractive and not repellent. After this experiment all parts of the plant were removed, leaving only the pot and soil in the plant chamber, and a control experiment (point G) was then conducted, which showed that everything was in good working order.

Finally, supposing that the emanations from plants are checked for a few days after the plants have been pulled up and potted, plant H was tested on the 9th and 19th day after being potted. The results (curves H and I) obtained are slightly better than usual; the highest percentage of attractiveness being 70.3 per cent, indicating that either the plant or the beetles were in better condition. The plant did not seem as thrifty as when pulled from the ground; the beetles were older, more nearly worn out, and they moved more slowly than usual. Another plant, J (curve J), was tested after having been potted for three days, but the percentages of attractiveness were not quite so high, although nearly constant.

The highest percentage of attraction obtained during the entire investigation as an average for 4 individual tests was 76.7 per cent (curve K), and in this experiment the beetles responded strongly to the plant emanations in each individual test. This percentage was obtained on September 8 by using three potato branches inserted in a bottle of water. On this date the surviving beetles were in a state of æstivation, but they could still move about slowly, although only a comparatively few responded to the light.

To conclude this section, 26 experiments were conducted in which living potato plants were used; all of these, except large plant E, gave percentages of attractiveness, although a few of the responses were weak and a few strong, the average for all being 62.7 per cent. In these 24 experiments, 98 individual tests were made; all of these, except 5,

showed percentages of attractiveness, and these 5 were near the neutral line of 50 per cent. The weak responses were perhaps mostly due to two factors: (1) the beetles were used repeatedly and in some cases till they almost ceased to respond to odors; and (2) some of the plants were aerated for several hours. As a rule the longer the beetles were tested, the less they responded to light and odors, and also it seemed that the longer a plant was aerated the fewer emanations it emitted. These observations are borne out by Figure 28, which clearly shows that the very first individual responses were usually the highest of all, then the curves drop suddenly, and thereafter as a rule descend more or less gradually.

To the writer a potato plant has a characteristic smell, although not so strong a one as those from some other plants. When enclosed in the plant chamber, its odors are perhaps emanated along with the water vapor, which judged from the condensed portion, was considerable. When a potato plant was removed from the plant chamber, a distinct odor was left behind, but the writer could not detect the plant odor in the Y-tubes after it had been drawn through them, although he could detect the insect odor after the beetles had once passed through the forks.

3. Responses of Potato Beetles to Emanations From Other Living Host Plants

Since potato beetles, when potato plants are scarce or entirely wanting, feed on the horsenettle (*Solanum carolinense* L.), jimsonweed (*Datura stramonium* L.), tomato (*Lycopersicum esculentum* Mill.), henbane (*Hyoscyamus niger* L.), and a few other related plants, all be-

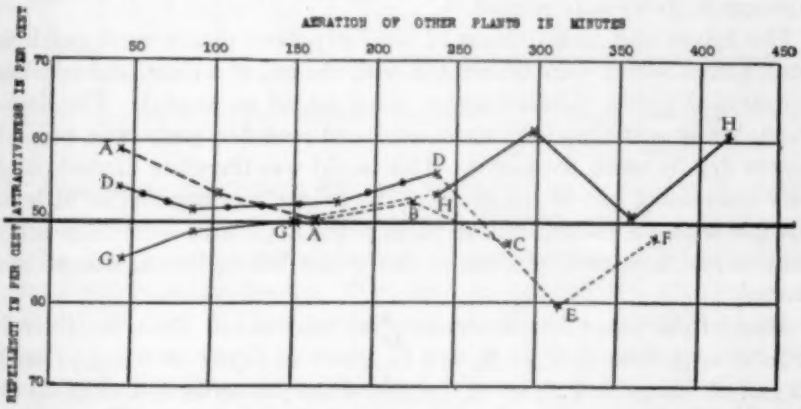

Fig. 29.—Curves showing responses of potato beetles to emanations from other living host plants; *A*—*A*, one horsenettle; point *B*, two horsenettles; point *C*, one-half horsenettle; *D*—*D*, one jimsonweed; point *E*, two jimsonweeds; point *F*, one-half jimsonweed; *G*—*G*, two tomato plants; and *H*—*H*, one tomato plant.

longing to the potato family (*Solanaceæ*), the preceding experiments were repeated, using some of these plants.

Most of the detailed results obtained are given in Table 2 and Figure 29. The uninjured horsenettles tested seemed thrifty and were about ready to bloom. To the writer they had almost no smell, but when the leaves were broken or crushed they emitted a characteristic odor. The beetles tested responded little and at times not at all to their emanations, although in potato patches it is common to see these insects on horsenettle.

The jimsonweed and tomato plants have strong and characteristic smells, and potato beetles do not feed on them unless forced to do so. The results obtained when using these two plants indicated that the beetles liked the emanations from the jimsonweed only slightly, and those from the single tomato plants rather more but no striking responses were obtained.

4. Responses of Potato Beetles to Odors From Water Extracts of Potato Foliage

In all the experiments dealing with water extracts and steam distillates, the plant chamber (Fig. 27, *C*) was disconnected by removing the tube C_3, and another tube like B_4 was inserted in bottle *B*. A definite quantity of extract or distillate was put in bottle *B* and an equal quantity of distilled water was put in the control bottle B_7. Y-tubes A and B were used alternately as usual; the position of one bottle was changed for that of the other; and four individual tests were considered one experiment, as already related.

The leaves and small stems of thrifty potato plants were cut into small pieces, which were macerated with the aid of a clean and odorless mortar and pestle, distilled water being added as needed. The dark-green liquid resulting was then decanted and the pulp was pressed almost dry by using the pestle. This liquid was therefore diluted plant juice containing bits of the plant. The foliage was handled as little as possible with the hands, and all parts of the apparatus were thoroughly cleaned and appeared odorless to the writer before the experiment was started.

Most of the other details obtained are recorded in Table 3. In each series of experiments A, C, E, and G, 25 cc. of liquid were had by using 25 gm. of foliage and 25 cc. of distilled water; in series B and D, 35 cc. and 25 cc., respectively, of liquid were had by using 50 gm. of foliage and 25 cc. of water; and in series F, 25 cc. of liquid were had by using 25 gm. of foliage and 35 cc. of water.

Table 3 and Figure 30 show that all the responses obtained were attractive, except two which were neutral, lying on or very near the division line of 50 per cent. The highest percentage of attractiveness obtained was 66.8 which is considerably lower than the highest attraction obtained when using emanations from potato plants. Comparing the curves in Figures 28 and 30, it will be noted that those in Figure 28 descend, as a rule from the highest points toward the neutral line, while those in Figure 30, ascend from the lowest points, indicating that the odors in the water extracts of potato foliage increase in attractiveness during the first four hours of aeration, after which they seem to decrease.

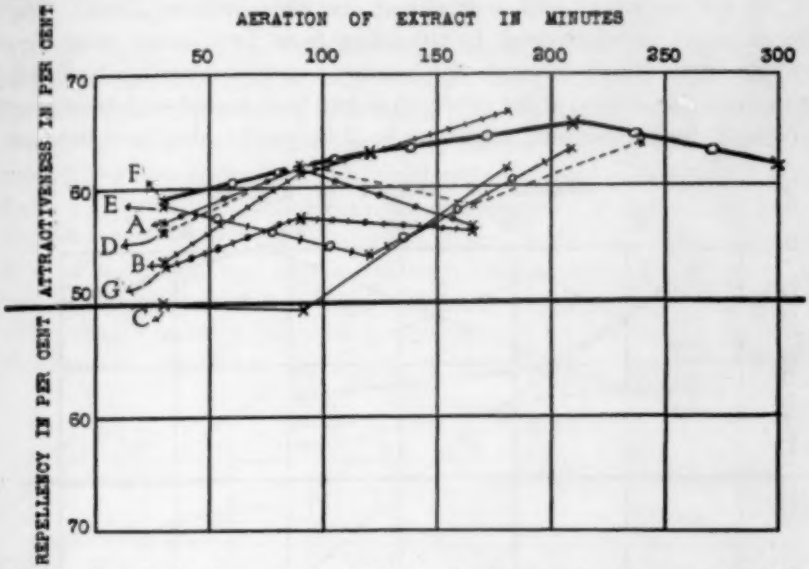

Fig. 30.—Curves showing responses of potato beetles to odors from water extracts of potato foliage; *A*—*G*, represents seven series of experiments

5. Responses of Potato Beetles to Odors From Water Extracts of Other Host Plants

The experiments reported in section 4 were repeated by using other plants which potato beetles often feed on, particularly when they are forced to do so. In five preliminary experiments in which water extracts of jimsonweed, tomato, and henbane, were used no attractive responses were obtained, probably because the beetles tested were in poor condition and the extracts were too concentrated. When these experiments were repeated, however, fairly good results were obtained.

In the series of experiments A (Table 4), 25 cc. of greenish liquid were

had by using 25 gm. of jimsonweed foliage and 25 cc. of distilled water; in series B, 30 cc. of brownish liquid were had by using 50 gm. of horsenettle and 50 cc. of water; in series C, 25 cc. of whitish liquid, turning brownish pink upon aeration, were had by using 50 gm. of small, young potatoes (skin and all) and 25 cc. of water; in series D, 50 cc. of dark greenish liquid were had by using 50 gm. of tomato foliage and 25 cc. of water; and in series E, 25 cc. of dirty liquid having a slightly decayed odor were had by using 25 gm. of slightly decayed henbane leaves and 35 cc. of water.

Table 4 and Figure 31 show that all the responses obtained were attractive, except one which was neutral and one which was repellent. The percentages of attractiveness to the odors from jimsonweed were surprisingly high, chiefly because the beetles tested had neither been fed nor used for two days. If the other odors had been tested with beetles in an equally good condition, responses to them might also have been as

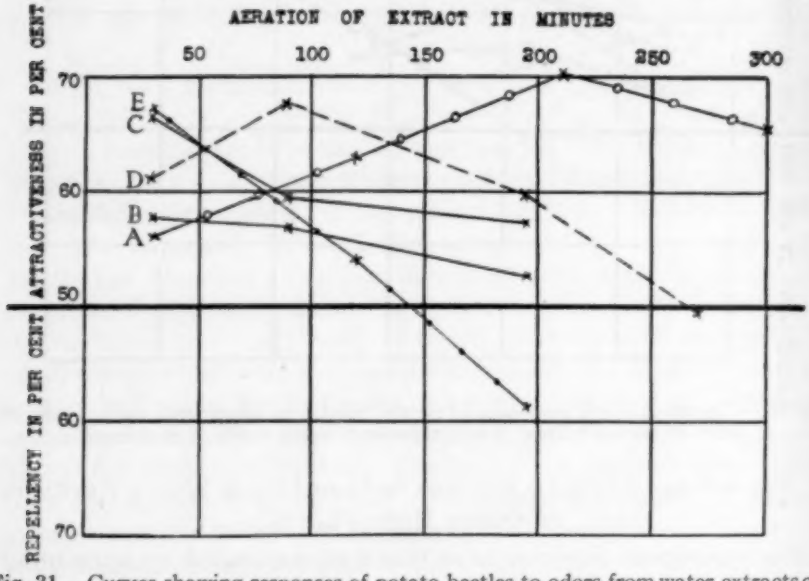

Fig. 31.—Curves showing responses of potato beetles to odors from water extracts of other host plants; *A*, jimsonweed; *B*, horsenettle; *C*, potato tuber; *D*, tomato plant and *E*, henbane.

high. In regard to the experiments consisting of 4 tests, the highest percentage of attraction to the odor from jimsonweed was 70.1 per cent; from horsenettle, 56.9 per cent; from potato tuber, 59.7 per cent; from tomato, 67.7 per cent; and from henbane 54 per cent. The henbane

leaves were in poor condition, having been kept on ice for several days. The responses to the odor from their extract started high with 67.4 per cent, but finally fell below the neutral line when the odor to the writer had become foul and unpleasant.

Potato beetles, either in confinement or in the field, are fond of henbane leaves. The surface and odor of these reminds one slightly of cabbage leaves, but more of kale leaves; although the odor from the juice is similar to that from potato leaves.

6. Responses of Potato Beetles to Odors from Steam Distillates of Potato Foliage and Potato Tubers

After trying an old copper still which could not be rid of its burntlike odors, a small glass still, free of odors and easily cleaned, was used. In the first three experiments *a*, *b*, and *c* (Table 5), the potato foliage was macerated with the aid of a clean and odorless mortar and pestle, distilled water was added, and the liquid and pulp were gently boiled in the flask, which was connected with the condenser by a glass tube and cork stoppers, and finally the condensed steam or distillate was collected. Since this method was not satisfactory, owing to the difficulty of preventing the pulp from scorching, and thereby changing the natural odor of the distillate, only plant juice was distilled for use in the remaining experiments. In these the foliage or tubers were ground in a meat

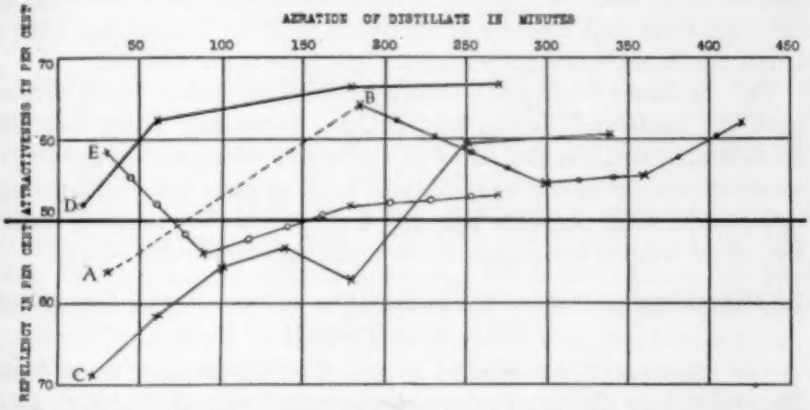

Fig. 32.—Curves showing responses of potato beetles to odors from steam distillates of potato foliage and potato tubers; *A* to *D*, potato foliage; *E*, potato tubers.

chopper. The resulting juice and bits of plant were then separated from the pulp by straining them through a clean cheesecloth.

In experiment *a* (Table 5), 45 cc. of distillate were collected by using

25 gm. of potato foliage and 40 cc. of distilled water. When tested this distillate was slightly attractive; but after standing overnight in the warm laboratory, it became slightly repellent (experiment *b*). To the writer its odor had considerably changed. In experiment *c*, 30 cc. of distillate were collected by using 60 gm. of foliage and 50 cc. of water. This distillate was less attractive.

In the series of experiments A and B (Table 5 and Fig. 32), 50 cc. of distillate were collected by using 120 cc. of foliage juice, which was repellent when first tested (point A), but after being aerated for 180 minutes became rather strongly attractive (curve B). In series C, 50 cc. of distillate were collected by using 110 cc. of juice. The apparatus was scented for only 5 minutes, after which it was decided to determine when the odors changed from repellent to attractive, even if a long series of experiments should wear out the beetles. This change took place during the period from 180 to 250 minutes of aeration (curve C). The last point in this curve shows that the attractive odor can be maintained for a short time in warm weather, for this distillate was kept on ice overnight. In series D, 25 cc. of distillate were collected by using 80 cc. of juice. During the first 15 minutes the odors from this distillate were practically neutral, then the responses rapidly became strongly attractive, reaching the highest point at 66.9 per cent.

In series E, 25 cc. of distillate were collected by using 100 cc. of juice from young, unpealed potatoes. The responses to the odors from this distillate were only slightly attractive, but if the beetles had been in better condition higher percentages might have been obtained.

The distillates from potato foliage and tubers, before being aerated, gave off moderately sharp and slightly unpleasant odors, but after considerable aeration the odors to the writer became pleasant and resembled those from boiling potatoes. In most cases the distillates were collected in three portions, but only the first ones were tested, because the others seemed less promising owing to their unnatural odors.

7. Responses of Potato Beetles to Odors From Steam Distillates of Foliage of Other Host Plants

The experiments reported in section 6 were repeated, using foliage from other host plants. In the series of experiments A (Table 6), 50 cc. of distillate were collected by using 110 cc. of juice from horsenettle. Its smell was similar to that from potato foliage, but was less sharp and the distillate was slightly cloudy; after being aerated for an hour its cloudiness increased and its odor had changed, slightly resembling that from boiling potatoes. The odors from this distillate were only slightly attractive (Fig. 33, curve A).

In series B, 50 cc. of distillate were collected by using 80 cc. of juice from jimsonweed. This distillate was clear and had a peculiar odor which was different from that of the plant. Throughout the series of experiments it was repellent (curve B), although a weaker one might have shown attractive responses.

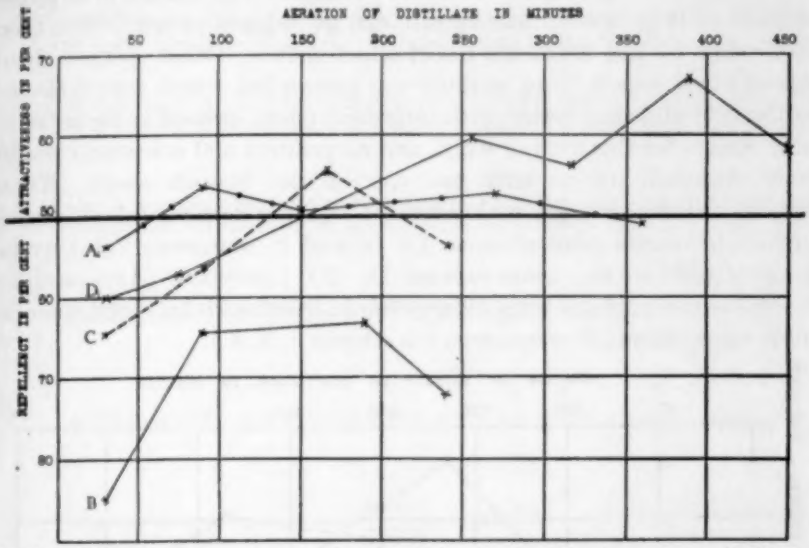

Fig. 33.—Curves showing responses of potato beetles to odors from steam distillates of foliage of other host plants: *A*, horsenettle; *B*, jimsonweed; *C*, tomato plant; and *D*, henbane.

In series C, 50 cc. of distillate were collected by using 85 cc. of juice from tomato plants. This distillate was slightly cloudy and had a peculiar odor, different from all the others yet mentioned. Its odors became attractive only at one point (curve C).

In series D, 25 cc. of distillate were collected by using a mixture of 50 cc. of distilled water and 25 cc. of juice from henbane leaves. The weak distillate was as clear as water and had a smell almost like that from potato leaves. At first it gave repellent responses, as did the other distillates, but later it gave strongly attractive ones, reaching the highest point at 67 per cent (curve D).

On several occasions 50 hungry beetles were put in a large pan, and after one piece of cotton had been soaked in water extract of potato foliage and another in distilled water, these were placed among the beetles. In every instance the beetles soon covered the cotton bearing the extract and tried to drink the liquid, but they paid little or no attention to the other piece of cotton. Similar results were obtained by

using distillate of potato foliage and distilled water; and also by using the first and second portions of the distillate of horsenettle with distilled water as a control.

Results Obtained With Other Insects

In the preceding pages it is shown that potato beetles, whose physiological state is more or less known, can be induced to respond to their food odors by the use of the insect olfactometer. Other species, about whose physiological state, nothing was known but which were collected in the field and then tested with their food odors, proved to be unfavorable insects for this kind of work, and no positive and consistent results were obtained, except with one species, the tussock moth. These insects included catalpa caterpillars (*Ceratomia catalpæ* Bdv.), meloid beetles (*Epicauta pennsylvanica* De G. and *E. marginata* Fab.), grasshoppers (*Melanoplus femur-rubrum* De G.), honeybees (*Apis mellifica* L.), harlequin cabbage bugs (*Murgantia histrionica* Hahn.), and tussock-moth caterpillars (*Hemerocampa leucostigma* S. & A.).

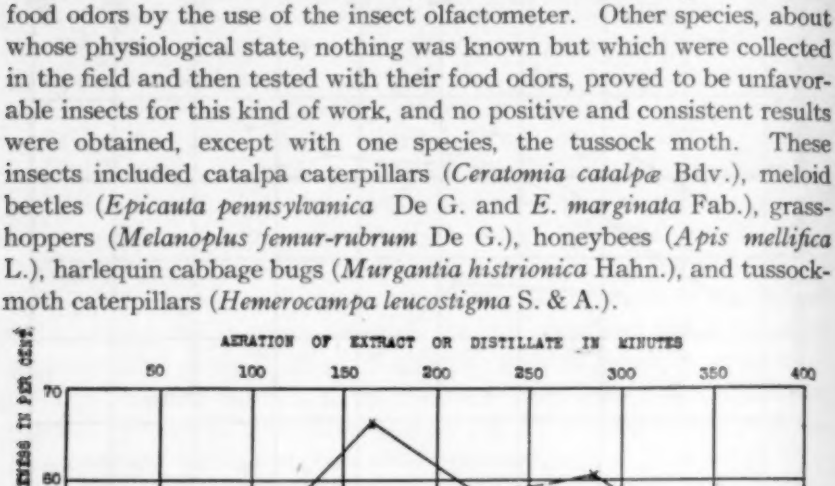

Fig. 34.—Curves showing responses of tussock-moth caterpillars to odors from water extract and steam distillate of elm leaves; *A*, water extract; and *B*, steam distillate.

1. Responses of Tussock-Moth Caterpillars to Odors From Water Extract and Steam Distillate of Elm Leaves

In the first experiment conducted (Table 7 and Fig. 34, curve A), 50 cc. of extract were had by using 6 gm. of ground elm leaves and 60 cc. of distilled water. In the second experiment conducted (curve B), 50 cc. of distillate were collected by using 15 gm. of ground leaves and 100 cc. of water. The responses to the odors from both of these substances were at first repellent but later became attractive.

TABLE 1. RESPONSES OF POTATO BEETLES TO EMANATIONS FROM LIVING POTATO PLANTS

Plants and controls	Per cent of beetles Repelled	Per cent of beetles Attracted	Aeration of plant	Set No.	Number of tests	Number of beetles in each test	Beetles which responded to light		Date	See curves and point in figure 28
			Minutes				*Number*	*Per cent*		
Small plant A	—	76.1	45	1	1	50	46	92.0	Aug. 3	curve A—A
ditto	—	64.3	120	1	4	50	185	92.5	Aug. 3	ditto
ditto	—	63.8	195	2	4	50	163	81.5	Aug. 3	ditto
ditto	—	59.2	270	3	4	50	179	89.5	Aug. 3	ditto
ditto	—	58.6	345	4	4	50	186	93.0	Aug. 3	ditto
Small plant B	—	72.3	45	1	1	50	47	94.0	Aug. 4	curve B—B
ditto	—	61.5	120	1	4	50	187	93.5	Aug. 4	ditto
ditto	—	68.4	195	2	4	50	187	93.5	Aug. 4	ditto
ditto	—	57.4	270	3	4	50	183	91.5	Aug. 4	ditto
ditto	—	59.3	345	4	4	50	189	94.5	Aug. 4	ditto
ditto	—	61.3	410	5	4	50	186	93.0	Aug. 4	ditto
Smaller plant C	—	68.9	15	1	1	50	45	90.0	Aug. 5	curve C—C
ditto	—	60.7	90	1	6	50	270	90.0	Aug. 5	ditto
ditto	—	58.6	150	7	4	50	174	87.0	Aug. 5	ditto
Control for plant C	—	52.2	210	2, 3	4	50	184	92.0	Aug. 5	curve D—D
ditto	—	52.0	270	3, 4	4	50	175	87.5	Aug. 6	ditto
ditto	—	50.3	330	4, 5	4	50	169	84.5	Aug. 6	ditto
Large plant E	65.3	—	15	7	1	50	46	92.0	Aug. 5	curve E—E
ditto	72.7	—	60	7	4	50	187	93.5	Aug. 5	ditto
ditto	67.4	—	120	5	4	50	184	92.0	Aug. 6	ditto
One-half of plant E	—	57.0	180	6	4	50	179	89.5	Aug. 6	curve F—F
ditto	—	58.2	240	1	4	50	170	85.0	Aug. 6	ditto
ditto	—	56.3	300	2	4	50	183	91.5	Aug. 6	ditto
ditto	—	56.3	360	7	4	50	183	91.5	Aug. 6	ditto
Control for plant E	—	51.4	420	7	4	50	181	90.5	Aug. 6	point G
Plant H, potted 9 days	—	71.4	45	1–11	1	50 ♀	35	70.0	Aug. 14	curve H—H
ditto	—	70.3	135	1–11	4	50 ♀	101	50.5	Aug. 14	ditto
ditto	—	69.7	225	1–11	4	50 ♂	119	59.5	Aug. 14	ditto
ditto	—	53.5	300	1–11	4	50	142	71.0	Aug. 14	ditto
Plant H, potted 19 days	—	81.2	60	1–11	1	50 ♀	16	32.0	Aug. 24	curve I—I
ditto	—	70.2	180	1–11	4	50 ♀	94	47.0	Aug. 24	ditto
ditto	—	64.1	300	1–11	4	50 ♂	156	78.0	Aug. 24	ditto
Plant J, potted 3 days	—	67.9	30	1–11	1	84 ♀	28	33.3	Aug. 27	curve J—J
ditto	—	64.7	150	1–11	4	84 ♀	85	25.3	Aug. 27	ditto
ditto	—	66.7	270	1–11	4	84 ♀	102	30.4	Aug. 27	ditto
ditto	—	67.4	390	1–11	4	84 ♀	92	27.4	Aug. 27	ditto
3 branches in water	—	66.7	60	1–11	1	50 ♀	9	18.0	Sept. 8	curve K—K
ditto	—	76.7	180	1–11	4	50 ♀	30	15.0	Sept. 8	ditto

TABLE 2. RESPONSES OF POTATO BEETLES TO EMANATIONS FROM OTHER LIVING HOST PLANTS

Kind and number of plants used	Per cent of beetles Repelled	Per cent of beetles Attracted	Aeration of plant	Set No.	Number of tests	Number of beetles in each test	Beetles which responded to light		Date	See curves and points in figure 29
			Minutes				*Number*	*Per cent*		
One horsenettle.....	—	59.1	45	7	1	50	44	88.0	Aug. 7	curve A—A
ditto	—	53.4	105	7	4	50	178	89.0	Aug. 7	ditto
ditto	—	50.3	165	6	4	50	163	81.5	Aug. 7	ditto
Two horsenettles....	—	52.6	225	5	4	50	133	66.5	Aug. 7	point B
One-half horsenettle.	52.7	—	285	3, 4	4	50	148	74.0	Aug. 7	point C
One jimsonweed.....	—	54.3	45	2, 4	1	50	46	92.0	Aug. 7	curve D—D
ditto	—	51.6	90	2, 4	4	50	188	94.0	Aug. 7	ditto
ditto	—	52.7	180	5, 6	4	50	184	92.0	Aug. 7	ditto
ditto	—	56.0	240	5, 6	4	50	159	79.5	Aug. 7	ditto
Two jimsonweeds...	60.1	—	315	2, 3	4	50	143	71.5	Aug. 8	point E
One-half jimsonweed.	51.9	—	375	3, 7	4	50	131	65.5	Aug. 8	point F
Two tomato.....	54.3	—	45	6, 7	1	50	46	92.0	Aug. 10	curve G—G
ditto	51.1	—	90	6, 7	4	50	176	88.0	Aug. 10	ditto
ditto	50.0	50.0	150	4, 5	4	50	168	84.0	Aug. 10	ditto
One tomato.....	—	53.1	240	2, 3	4	50	145	72.5	Aug. 10	curve H—H
ditto	—	61.1	300	1, 7	4	50	126	63.0	Aug. 10	ditto
ditto	—	50.4	360	4, 5	4	50	117	58.5	Aug. 10	ditto
ditto	—	60.5	420	2, 3	4	50	129	64.5	Aug. 10	ditto

TABLE 3. RESPONSES OF POTATO BEETLES TO ODORS FROM WATER EXTRACTS OF POTATO FOLIAGE

Series of experiment	Quantity of extract used	Per cent of beetles Repelled	Attracted	Aeration of extract	Set No.	Number of tests	Number of beetles in each test	Beetles which responded to light		Date	See curves in figure 30
				Minutes				*Number*	*Per cent*		
A	25 cc.	—	57.4	30	13	1	50	47	94.0	June 13	curve A
		—	61.7	90	13	4	50	191	95.5	June 13	ditto
		—	56.8	165	13	4	50	190	95.0	June 13	ditto
B	35 cc.	—	53.7	30	13, 14	1	50	41	82.0	June 15	curve B
		—	61.3	90	13, 14	4	50	142	71.0	June 15	ditto
		—	66.5	180	13, 14	6	50	203	66.8	June 15	ditto
C	25 cc.	50.0	50.0	30	15, 16	1	50	44	88.0	June 17	curve C
		50.3	—	90	15, 16	4	50	173	86.5	June 17	ditto
		—	61.7	180	17	6	50	209	69.7	June 17	ditto
D	25 cc.	—	56.4	30	16, 17	1	50	39	78.0	June 20	curve D
		—	62.0	90	16, 17	4	50	166	83.0	June 20	ditto
		—	58.9	165	18	4	40 ♀	107	66.9	June 20	ditto
		—	64.0	240	19	4	48 ♂	136	70.8	June 20	ditto
E	25 cc.	—	58.8	30	10	1	50	34	68.0	July 23	curve E
		—	54.1	120	10	6	50	196	65.3	July 23	ditto
		—	63.1	210	8, 9	4	40	130	81.2	July 24	ditto
F	25 cc.	—	59.0	30	8, 9, 10	1	50	39	78.0	Aug. 1	curve F
		—	63.0	120	8, 9, 10	4	50	154	77.0	Aug. 1	ditto
		—	65.8	210	8, 9, 10	4	50	120	60.0	Aug. 1	ditto
		—	61.8	300	8, 9, 10	4	50	110	55.0	Aug. 1	ditto
G	25 cc.	—	53.2	30	1–11	1	50 ♀	47	94.0	Aug. 14	curve G
		—	57.5	90	1–11	4	50 ♀	174	87.0	Aug. 14	ditto
		—	56.2	165	1–11	4	50 ♀	130	65.0	Aug. 14	ditto

TABLE 4. RESPONSES OF POTATO BEETLES TO ODORS FROM WATER EXTRACTS OF OTHER HOST PLANTS

Series of experiments	Kind and quantity of extract used	Per cent of beetles Repelled	Attracted	Aeration of extract	Set No.	Number of tests	Number of beetles in each test	Beetles which responded to light		Date	See curves in figure 31
				Minutes				*Number*	*Per cent*		
A	Jimsonweed,	—	56.1	30	8, 9, 10	1	50	41	82.0	July 31	curve A
	25 cc.	—	62.8	120	8, 9, 10	4	50	148	74.0	July 31	ditto
		—	70.1	210	8, 9, 10	4	50	144	72.0	July 31	ditto
		—	65.3	300	8, 9, 10	4	50	147	73.5	July 31	ditto
B	Horsenettle,	—	57.9	30	15, 16	1	50	38	76.0	June 17	curve B
	30 cc.	—	56.9	90	15, 16	4	50	174	87.0	June 17	ditto
		—	52.3	195	15, 16	6	50	261	87.0	June 17	ditto
C	Potato tuber,	—	66.7	30	17	1	50	44	88.0	June 18	curve C
	25 cc.	—	59.7	90	17	4	50	178	89.0	June 18	ditto
		—	57.2	195	17	6	50	215	71.7	June 18	ditto
D	Tomato,	—	61.1	30	9	1	25	18	72.0	July 21	curve D
	50 cc.	—	67.7	90	9	4	25	62	62.0	July 21	ditto
		—	59.6	195	8, 9	4	50	134	67.0	July 21	ditto
		50.7	—	270	8, 9	4	50	150	75.0	July 21	ditto
E	Henbane,	—	67.4	30	8, 9, 10	1	50	43	86.0	July 28	curve E
	25 cc.	—	54.0	120	8, 9, 10	4	50	163	81.5	July 28	ditto
		58.8	—	195	8, 9, 10	4	50	114	57.0	July 28	ditto

TABLE 5. RESPONSES OF POTATO BEETLES TO ODORS FROM STEAM DISTILLATES OF POTATO FOLIAGE AND POTATO TUBERS

Series of experiments	Kind and quantity of distillate used	Per cent of beetles Repelled	Per cent of beetles Attracted	Aeration of distillate *Minutes*	Set No.	Number of tests	Number of beetles in each test	Beetles which responded to light *Number*	Beetles which responded to light *Per cent*	Date	Remarks, and see points and curves in figure 32
	Potato: foliage,										
a	45 cc.	—	56.5	80	13, 14	6	50	177	59.0	June 15	fresh weak distillate
b	ditto	56.9	—	60	13, 14	4	50	181	90.5	June 16	stood over night
c	30 cc.	—	54.4	80	13–19	6	50 ♀	193	64.3	June 24	weak distillate
A	50 cc.	56.1	—	30	13–19	1	50 ♂	41	82.0	June 25	point A
B	ditto	—	64.2	180	13–19	4	50 ♀	109	54.5	June 25	curve B
	ditto	—	54.6	300	13–19	4	50 ♂	86	43.0	June 25	ditto (worn out)
	ditto	—	55.5	360	12	4	16	45	70.3	June 25	ditto (ditto)
	ditto	—	62.0	420	13–19	4	44	79	44.3	June 25	ditto
C	50 cc.	68.8	—	20	13–19	1	52 ♀	48	92.3	June 26	curve C
	ditto	61.6	—	60	13–19	4	52 ♀	190	91.3	June 26	ditto
	ditto	55.6	—	100	13–19	4	52 ♀	187	89.9	June 26	ditto
	ditto	53.0	—	140	13–19	4	52 ♀	149	71.6	June 26	ditto
	ditto	57.0	—	180	13–19	4	52 ♀	107	51.4	June 26	ditto (worn out)
	ditto	—	59.6	250	13–19	4	43	89	51.7	June 26	ditto
	ditto	—	60.4	340	13–19	4	50 ♀	187	93.5	June 27	ditto
D	25 cc.	—	51.9	15	8, 9, 10	1	50	27	54.0	July 28	curve D
	ditto	—	62.5	60	8, 9, 10	4	50	88	44.0	July 28	ditto
	ditto	—	66.4	180	8, 9, 10	4	50	134	67.0	July 28	ditto
	ditto	—	66.9	270	8, 9, 10	4	50	121	60.5	July 28	ditto
E	tuber 25 cc.	—	58.6	30	13–19	1	46	29	63.0	June 27	curve E
	ditto	53.9	—	90	13–19	4	46	128	69.5	June 27	ditto
	ditto	—	52.1	180	13–19	4	50 ♀	96	48.0	June 27	ditto (worn out)
	ditto	—	53.2	270	13–19	4	50	77	38.5	June 27	ditto (worn out)

TABLE 6. RESPONSES OF POTATO BEETLES TO ODORS FROM STEAM DISTILLATES OF FOLIAGE OF OTHER HOST PLANTS

Series of experiment	Kind and quantity of distillate used	Per cent of beetles Repelled	Per cent of beetles Attracted	Aeration of distillate *Minutes*	Set No.	Number of tests	Number of beetles in each test	Beetles which responded to light *Number*	Beetles which responded to light *Per cent*	Date	See curves in figure 33, and remarks
	Horsenettle,										
A	50 cc.	53.6	—	30	13–19	1	50♂	41	82.0	June 29	curve A
	ditto	—	53.6	90	13–19	4	50♂	153	76.5	June 29	ditto
	ditto	—	50.5	150	13–19	4	50	99	49.9	June 29	ditto
	ditto	—	52.8	270	13–19	4	50♀	72	36.0	June 29	ditto (worn out)
	ditto	51.0	—	360	13–19	4	50♂	100	50.0	June 29	ditto
	Jimsonweed,										
B	50 cc.	85.0	—	30	8, 9	1	25	20	80.0	July 20	curve B
	ditto	64.2	—	90	8, 9	4	25	81	81.0	July 20	ditto
	ditto	63.1	—	180	8, 9	4	25	84	84.0	July 20	ditto
	ditto	72.1	—	240	10, 11	4	25	68	68.0	July 20	ditto
	Tomato,										
C	50 cc.	64.7	—	30	8	1	25	17	68.0	July 22	curve C
	ditto	56.6	—	90	8	4	25	53	53.0	July 22	ditto
	ditto	—	55.8	165	8, 9	4	38	77	50.7	July 22	ditto
	ditto	53.8	—	240	8, 9	4	50	78	39.0	July 22	ditto
	Henbane,										
D	25 cc.	60.0	—	30	8	1	25	20	80.0	July 24	curve D
	ditto	57.3	—	75	8	4	25	75	75.0	July 24	ditto
	ditto	—	59.6	255	8, 9	4	40	136	85.0	July 27	ditto
	ditto	—	56.1	315	8, 9	4	40	123	76.9	July 27	ditto
	ditto	—	67.0	390	8, 9	4	40	97	60.6	July 27	ditto
	ditto	—	58.0	450	8, 9	4	40	99	61.9	July 27	ditto (worn out)

TABLE 7. RESPONSES OF TUSSOCK-MOTH CATERPILLARS TO ODORS FROM WATER EXTRACT AND STEAM DISTILLATE OF ELM LEAVES

Kind of substance and quantity used	Per cent of insects Repelled	Per cent of insects Attracted	Aeration of extract or distillate	Set No.	Number of tests	Number of insects in each test	Insects which responded to light		See curves Date in figure 34
			Minutes				*Number*	*Per cent*	
Extract, 50 cc.....	52.2	—	30	5	1	50	23	46.0	July 3 curve A
ditto	—	50.6	90	5	4	50	83	41.5	July 3 ditto
ditto	—	66.7	165	5	4	50	75	37.5	July 3 ditto
ditto	—	54.0	255	6	4	50	89	44.5	July 3 ditto
Distillate, 50 cc.....	60.0	—	30	4	1	50	30	60.0	July 3 curve B
ditto	58.2	—	90	4	4	50	122	61.0	July 3 ditto
ditto	—	58.3	210	4	4	50	72	36.0	July 3 ditto
ditto	—	60.7	285	3	4	50	112	56.0	July 3 ditto
ditto	—	51.2	360	6	4	50	84	42.0	July 3 ditto

Scientific Notes

A Boll Worm Infesting *Gossypium davidsonii* in Sonora, Mexico. On December 9, 1925, in connection with a trip for the study of wild cottons in company with Mr. O. F. Cook and Mr. J. W. Hubbard, of the Bureau of Plant Industry of the U. S. Department of Agriculture, I found a Lepidopterous larva attacking the bolls of *G. davidsonii* near Guaymas, Sonora, Mexico. Adults were bred out and transmitted to the Bureau of Entomology for identification, and I am advised by a letter from Dr. Howard that Mr. William Schaus determined them as *Rhodoneura terminalis*. I am further advised that the species was originally described by Walker from Santo Domingo, presumably West Indies. Dr. Schaus has collected this species in Costa Rica, and has also received specimens from Calderon in Salvador which were said to be infesting the stems of the cotton plant.

The green bolls of *G. davidsonii* which were very abundant at the time of my observations were infested by the worm to the extent of about 5%. All of the specimens were found in the interior of the bolls, the full grown worms in several instances having consumed the entire contents. The full grown bolls were 14 to 15 mm. in diameter and 10 mm. long. The worms when full grown were about 14 mm. long and slightly over 3 mm. wide. The head was noted as reddish brown, the prothoracic shield smoky black, the body whitish with smoky tubercles from which arise short spines. This species has never so far been found by me on any other species of wild cotton or on cultivated cotton on the Mexican West Coast. At present it may be regarded as an insect which is potentially injurious to cultivated cotton. It is planned to plant some cultivated cottons in a locality where this insect was found attacking *G. davidsonii* with a view to observing its adaptability to the cultivated species of Gossypium.

A. W. MORRILL

ROCKY MOUNTAIN CONFERENCE OF ENTOMOLOGISTS AUGUST 16–21

The Fourth Rocky Mountain Conference of Entomologists will be held in Pingree Park, Colorado, August 16 to 21. Announcements to this effect have been mailed to many, but it is impossible for us to reach all by letter, so we hope the readers of this notice in the JOURNAL will feel free to get in touch with the Secretary if they are interested.

The meeting takes the form of an informal conference and an outing that in the past has proven very profitable and enjoyable. A commodious mountain lodge, owned by the Colorado Agricultural College, is made the headquarters. This is located at an altitude of about 9,000 feet in a small mountain park that is beautifully surrounded by snow-capped mountains. Accommodations and transportation to the park will be furnished to the entomologists and their families at actual cost. Since the crowd must be taken care of 55 miles from the base of supplies, it will be appreciated if those that are interested will notify us as far in advance as possible.

A project is under way leading to a list of the insects of this high altitude mountain park. The fauna is varied enough to permit all to enter into this. Your cooperation will be most welcome.

A tentative program will be available a little later.

GEORGE M. LIST, *Secretary, Fort Collins, Colorado*

JOURNAL OF ECONOMIC ENTOMOLOGY

OFFICIAL ORGAN AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

JUNE, 1926

The editors will thankfully receive news matter and other items likely to be of interest to our readers. Papers will be published as far as possible in the order of reception, except that papers of reasonable length may be accepted in the discretion of the editor for early publication, at $2.50 per page for all matter in excess of six printed pages; in the case of other matter, the maximum of 2,500 words is still operative. Photo-engravings may be obtained by authors at cost.

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The economic entomologist must continually keep in mind three important methods of control which may be termed natural, modified environmental and direct repressive measures. The last is visible, capable of producing tangible results and on these accounts alone appeals strongly to those anxious to correct an undesirable condition. It is obvious that natural checks, parasites, predators, adverse climatic conditions and the like have been operating for ages and apparently with a reasonable degree of success, broadly considered. Some attention has been given to certain aspects of the first phase, namely the introduction and establishment of beneficial parasites and predators and comparatively little to other phases, such as influence of climate, especially seasonal changes, though it is well known that these have a most important effect upon the abundance of insect life. The Insect Pest Survey is studying problems of this nature and yet much serviceable information in this field probably remains unrecorded because of a failure to appreciate its value when brought together in a coördinated whole. The influence of the modified environment, sometimes made practical to a certain extent and designated in one phase commonly as "clean culture," is a field of effort habitually greatly underestimated. Economical insect control is rarely accomplished by one method. It is usually brought about by a combination. The purpose of these few lines is to call attention to the broader aspects of many of our problems and to suggest that in some cases the concrete and obvious may really blind us to more rational and effective measures.

Obituary

HERBERT POLAND WOOD

Recently the writer has learned with deep regret of the death of his former associate, Mr. H. P. Wood, which occurred in Massachusetts on April 27, 1925.

Mr. Wood was born at South Attleboro, Massachusetts, August 12, 1883. He graduated at Massachusetts Agricultural College in 1907 with the degree of B. S. He was appointed in the Bureau of Entomology November 1, 1907, and was assigned to the Dallas, Texas, Laboratory where he began biological work with ticks. He continued research work relating to medical entomology until his transfer to the Cereal and Forage Insect Investigations in 1920.

The season of 1913 was spent in Bitter Root Valley of Montana on the Rocky Mountain spotted fever problem, and the summer of 1919 in Illinois, where he developed a very successful method of local eradication of the feather mite of poultry. He spent the winter of 1914-15 in taking Post Graduate work in the Harvard School of Tropical Medicine, and during that period was married to Miss Esther Davidson.

Mr. Wood's name appears as author or co-author of ten bulletins or scientific articles which deal with biological or control studies of ticks, and mites and lice affecting poultry. His work in this field is recognized as being very thorough and painstaking and the control measures he helped to develop are of far reaching economic importance.

After being transferred to the corn borer investigation, Mr. Wood carried on biological studies with that insect at Scotia and Silver Creek, New York, and Sandusky, Ohio. He resigned from the Government Service in 1923 to take up commercial work in Massachusetts, where he was located at the time of his death. He is survived by his wife and three children.

F. C. BISHOPP

Reviews

Applied Entomology, An Introductory Text-book of Insects in their Relations to Man by H. T. FERNALD, Second Edition, pages i-xiv, 1–395, 388 text illustrations, McGraw-Hill Book Company, Inc., New York, 1926.

A well written book needs little revision except as this may be necessitated by advances in knowledge and changed conditions. These have evidently been the

controlling factors in this new edition, there being some changes in relation to insecticides, particularly a fuller treatment of nicotine in its various forms and the recently discovered calcium cyanide. There are also some changes in the treatment of groups or individual species, as for example, the oriental peach moth, to accord more closely with the changes of the past five years. The chapter on "animals not insects with which the entomologist is expected to deal," although comprising but four pages, gives most useful information concerning a number of forms commonly brought to the entomologist and incidentally raises a question as to why, from the practical standpoint, an entomologist should not be an economic zoologist. Systematic divisions are necessary but they should not be construed too closely in practical matters.

The volume holds its place as one of the most satisfactory and comprehensive texts on American insects.

E. P. FELT

The Nematode Parasites of Vertebrates by WARRINGTON YORKE and P. A. MAPLESTONE, pages i–xi, 1–536, text illustrations 307, P. Blakiston's Sons and Co., Philadelphia, Pa.

This, the first comprehensive single volume to present a systematic account of the nematode parasites of vertebrates opens a new and important field with its keys and characterizations of groups and genera,its numerous excellent illustrations, the index of specific names with recorded vertebrate hosts, and the extensive bibliography. The recently discovered cause of the damp sand type of creeping eruption of our southeastern states, the microscopic third instar of *Agamonematodum migrans*, belongs in this group. Filaria in man and other animals and its dissemination by mosquitoes, Ascaris of man and the Habronema of the horse and its relation to the house fly are points of contact between helminthology and entomology. Reference to Pierce's Sanitary Entomology discloses a somewhat general occurrence of nematodes in insects and in some cases at least the alternate hosts are vertebrates. By no means has all been learned about this group, particularly in relation to insect hosts.

The avowed purpose of the work is to simplify the process of naming Nematode parasites and in this way, if in no other, it is bound to stimulate interest in the entire group. This volume should be on the reference shelves of every entomologist interested in the broader phases of his subject, particularly students of medical entomology.

It would be a great boon if there were a comparable work on the free living nematodes, forms which occur in arid deserts, in the Antarctic ice and at enormous depths in alpine lakes and the ocean—largely an unknown fauna dependent upon winds, birds and animals for distribution, and yet comparable with insects in the number of species and economic importance. The day must come when knowledge concerning the entire group is systematized and presented in a convenient compendium such as the work under review.

E. P. FELT

The Mosquitoes of California, by STANLEY B. FREEBORN, Univ. Calif. Publ., Tech. Bull. V. 3, No. 5, pp. 333–460, 41 text figures, March 24, 1926.

This comprehensive ecological account is a most admirable addition to Culicid literature, giving as it does detailed descriptions and ecological data on the various forms, with keys for the separation of the genera on adult characters, based on both general characteristics and the terminalia and also for the larvae, and in addition there are keys for the separation of the species upon both adult and larval characteristics. There is an excellent series of illustrations of the essential characters in both adult and immature stages. The publication is largely economic, since mosquito control rests in final analysis upon an accurate knowledge of the group and a thorough acquaintance with the ecology of the species involved.

The ecological data has been gathered over a period of 9 years and the local investigations occupied 3 summers and extended into all sections of the state. These gave an exceptional opportunity to ascertain the status of the various species which are divided on practical grounds into salt marsh breeders, mountain species and the malarial carrying Anopheles. The writer has exercised a very commendable conservatism and recognized relatively few genera and species. The depth of the nomenclatural nightmare in this group, possibly inseparable from intensive, simultaneous studies by a number of investigators upon many variable forms, is indicated by the 47 synonyms, 4 with the much overworked prefix Pseudo, of the genus Aedes, the 32 synonyms of Culex, including among others the unwieldy Pseudoheptaphlebomyia, and the 36 synonyms of Anopheles, the author referring to the elucidation of this complex as a "confusing and almost impossible undertaking." It should be noted in passing that the erection of this relatively large proportion of invalid genera and their reduction to synonomy involves an enormous expenditure of time which, if it could have been avoided, might have saved time for studies along more productive lines.

This is a part, we are informed, of a thesis presented for the degree of Doctor of Philosophy at the Massachusetts Agricultural College, there being in addition a discussion of terminology published in the American Journal of Hygiene (Vol. 4, May 1924) and a large unpublished section on ecology.

This paper might well serve as a model for the treatment of mosquitoes from other sections of the country. A well selected bibliography and a detailed index adds greatly to the value of this paper.

E. P. FELT

Current Notes

Dr. M. D. Leonard is now entomologist of the Wilson Toomer Fertilizer Company, Orlando, Fla.

Mr. Kenyon F. Chamberlain of Cornwall, Conn., has a provisional appointment as Assistant State Entomologist of New York pending a Civil Service examination.

Mr. Henry L. Viereck, Assistant Entomologist and Specialist in Hymenoptera, resigned from the Entomological Branch, Canadian Department of Agriculture, to take effect April 1.

According to *Science*, Dr. Albert H. Tuttle, a Boston surgeon and formerly an instructor in entomology at the Bussey Institution of Harvard University, died March 1.

Recent visitors to the Arlington, Mass. laboratory of the Bureau of Entomology included S. S. Crossman, C. W. F. Muesebeck, P. B. Dowden, W. A. Osgood and P. W. Dempsey.

According to *Science*, Dr. J. M. Aldrich, Associate Curator and Specialist in Diptera, U. S. National Museum, planned to leave April 1, for Guatemala, to study and collect parasitic Diptera.

Mr. Paul A. Davis has been appointed Assistant in Entomology, Connecticut Agricultural Experiment Station, to study the life history and habits of the Asiatic beetle, *Anomala orientalis*, at the infestation in New Haven.

Mr. L. G. Gentner of the Michigan Agricultural College, East Lansing, Mich., spent a number of days at the U. S. National Museum in March, consulting collections of Coleoptera and conferring with Mr. Barber.

The Department of Entomology of the Kansas State Agricultural College have adopted and are now installing the tray system for their permanent insect collection. The U. S. National Museum type of drawers and pasteboard tray sizes are being used.

According to *Science*, Benjamin Pickman Mann, Examiner in the U. S. Patent Office, and at one time Assistant Entomologist in the Bureau of Entomology of the U. S. Department of Agriculture, died March 22, aged 78 years.

Mr. A. C. Mason of the Bureau of Entomology, who has recently been stationed at Linsay, Calif., investigating the California orange thrips, has been transferred to Hawaii, where he will study the Mediterranean fruit fly.

Captain D. L. VanDine, Director for Cuba of the Tropical Plant Research Foundation, recently visited the Sugar Cane Insect Laboratory of the U. S. Bureau of Entomology, at New Orleans, La., for conference concerning future projects.

The Division of Tropical and Subtropical Fruit Insect Investigations of the Bureau of Entomology, temporarily combined with the Division of Deciduous Fruit Insect Investigations, has been given separate status and Dr. A. C. Baker placed in charge.

Mr. E. Avery Richmond, of the Japanese Beetle Laboratory, Riverton, N. J., addressed the Philadelphia U. S. D. A. Club on February 17, on "Recent Developments in Japanese Beetle Control." His talk was illustrated with a number of photographs and charts.

A recent reorganization of the quarantine division resulted in the placing of F. H. Worsinger, Jr., in charge of all the chemical treatments of soil and nursery stock, as required under the regulations of the Japanese beetle quarantine.

This year Dr. Böving has again received a very valuable addition to the U. S. National Museum collection. Seventy-seven vials containing coleopterous larvae, most of the material having been reared, were sent him by E. Rosenberg of Copenhagen, Denmark.

A collection of forty or fifty species of Coleoptera has been donated to the Canadian National Collection by Mr. F. S. Carr, of Medicine Hat, Alta. Most of the species were not represented in the collection at Ottawa.

Mr. J. Peter Johnson resigned from the Bureau of Entomology, effective April 1, and was soon appointed by the Connecticut Agricultural Experiment Station to take charge of the quarantine and control work against the Asiatic beetle, at New Haven, Conn.

Resignations from the Bureau of Entomology have recently been announced as follows: J. B. Cronin, Junior Entomologist, Japanese Beetle Investigations, to accept a position with the American Cyanamid Company; A. C. Johnson, Tallulah, La.; C. G. Wallace, Collaborator, Miss.; and J. P. Johnson, Riverton, N. J.

Professor W. C. O'Kane and M. F. Crowell called at the Arlington, Mass., Laboratory of the Bureau of Entomology on February 5 for a conference regarding the progress of the cooperative work on the corn borer between the Bureau and the New Hampshire Experiment Station.

Several cases of "powder-post" beetle injury to furniture by imported European Anobiid beetles have recently been found in this country. In one instance living lepidopterous larvae of unknown species were found in the infested furniture, utilizing the burrows of the powder-post beetles.

Messrs. N. F. Howard and J. E. Dudley, Jr., Associate Entomologists Bureau of Entomology, stationed at Columbus, Ohio, and Madison, Wis., attended the meetings of the North-Central States Entomologists at Urbana, Ill., March 4 and 5, and discussed the pea aphis and Mexican bean beetle projects.

The second annual meeting of the Kansas Entomological Society was held on April 24th, at Lawrence, Kansas. The program consisted of informal talks on the entomological problems under way in the state. Officers elected for the ensuing year are Dr. R. C. Smith, president, and R. H. Beamer, secretary.

According to *Science*, Dr. L. O. Howard, Chief of the Bureau of Entomology, will deliver an address on "Insects and Human Progress" following the annual dinner in connection with the Pacific Division of the American Association for the Advancement of Science, at Mills College, Calif., June 16.

The following members of the Cereal and Forage Insect Investigations staff of the Bureau of Entomology, attended the meeting of the North-Central States Entomologists held at Urbana on March 4 and 5: W. H. Larrimer, W. B. Cartwright, W. B. Noole, J. R. Horton, A. F. Satterthwait, C. N. Ainslie, and L. H. Worthley.

Dr. W. H. Larrimer, in charge of Cereal and Forage Insect Investigations of the Bureau of Entomology, visited Atlantic City on February 17 and 18, to confer with Arthur Gibson, of the Canadian Department of Agriculture, who was attending a meeting there of the New Jersey Mosquito Extermination Association.

Dr. Charles C. Adams, Professor of Forest Zoology and Director of the Roosevelt Wild Life Forest Experiment Station of the New York State College of Forestry, Syracuse, has resigned to become Director of the New York State Museum at Albany, succeeding the late Dr. John M. Clarke.

Messrs. Norman Criddle and C. B. Hutchings, Entomological Branch, Canada Department of Agriculture, acted as judges of insect collections at the Boy's Hobby Show, held at the Y. M. C. A., Ottawa, March 11–13. Mr. Criddle left Ottawa on March 20 for Treesbank, Man., after spending the winter months reclassifying the Coleoptera in the Canadian National Collection.

Mr. R. Glendenning of the Agassiz Laboratory Entomological Branch, was re-elected Secretary-Treasurer of the Entomological Society of British Columbia, at the annual meeting held at Victoria, on February 27. Owing to recommendations advanced by Mr. Glendenning, the City of Vancouver has appropriated $9,000 to carry out a control campaign against the European earwig.

Paratypes of three species of Chalcidoidea described by P. H. Timberlake, of the California Citrus Experiment Station at Riverside, have been added recently to the U. S. National Museum collection. Mr. Timberlake, whose work in this group is well known, has consistently followed the practice of depositing representatives of his species in the National Collection.

Mr. H. S. Peters, a postgraduate student of Ohio State University, spent his spring vacation at the U. S. National Museum identifying his collection of Ohio Mallophaga and making notes on some of the material in the collection. Mr. Hugh Miley, another postgraduate student of Ohio State University, recently spent several days at the Museum studying the Myriapoda.

Messrs. L. B. Smith and J. L. King visited New Haven, Conn., March 25 and 26, conferring there with Dr. W. E. Britton and Director Slate, of the Connecticut Agricultural Experiment Station, on proposed control operations to be undertaken against the Asiatic beetle, *Anomala orientalis* Waterh. While there, Mr. Smith addressed a public meeting of residents of the community where the Asiatic beetle occurs.

At a meeting of the Entomologists group of the Professional Institute of the Civil Service of Canada, held in the Entomological Branch on March 17, Mr. Gibson presented a paper on "James Fletcher, Gentleman and Entomologist." This paper discussed the life of Fletcher and the valuable work he rendered Canada while Entomologist of the Department of Agriculture.

According to *Science*, the former pupils, colleagues, and friends of William Lochhead, Emeritus Professor of Entomology and Zoology in MacDonald College of McGill University, have subscribed toward his portrait, which has been painted in oil by Mr. G. Horne Russell, President of the Royal Canadian Academy. The portrait was unveiled on March 17 by Sir Arthur Currie, Vice-Chancellor and Principal of the University.

On the recommendation of Prof. F. V. Theobald, Mr. H. F. Barnes, a Scholar of the Ministry of Agriculture and Fisheries, will spend a part of his scholarship, some five months beginning October first, studying the gall midges, Itonididae, under the direction of Dr. E. P. Felt, State Entomologist of New York.

The Alabama Polytechnic Institute, Auburn, Ala., has recently completed a 1000-watt broadcasting station, WAPI, meter length 248. It is the plan to broadcast agricultural and other lectures each week. The department of Zoology and Entomology is cooperating in this work by giving a series of lectures on household insect pests, boll weevil information, honey bee talks, and lectures in ornithology.

Messrs. L. H. Worthley, D. J. Caffrey, and K. W. Babcock, of the Arlington, Mass., Laboratory, visited Washington on February 13, on business concerned with European corn borer activities. Mr. Caffrey and Mr. Babcock remained several days, making arrangements for further ecological work on the insect in Europe. Mr. Worthley visited New Haven, Conn., on April 16 and May 4 to confer regarding corn borer control work.

In February a small but extremely valuable collection, comprising about 150 specimens of holotypes and paratypes of twenty-three species of parasitic Hymenoptera belonging to the superfamily Chalcidoidea, were received by A. B. Gahan for

the U. S. National Collection. They include representatives, in most cases holotypes, of all of the species thus described by Harold Compere, of the California Citrus Experiment Station, Riverside, Calif., a rising young chalcidologist, who has contributed them.

Recent visitors to the Japanese beetle laboratory at Riverton, N. J., included Arthur Gibson, Dominion Entomologist of Canada, Dr. H. C. Huckett, Assistant Entomologist of the New York Agricultural Experiment Station, stationed at Riverhead, Long Island, Professor J. S. Houser, Entomologist, Ohio Station, Wooster, Ohio, William L. Slate, Jr., Director, and Messrs. R. B. Friend and Paul A. Davis, Assistant Entomologists, Agricultural Experiment Station, New Haven, Conn., and Mr. F. L. Gambrill, Assistant Entomologist, New York Agricultural Experiment Station, Geneva, N. Y.

Dr. R. J. Tillyard, Entomologist and Chief of Biological Department, Cawthron Institute of Scientific Research, Nelson, New Zealand, arrived at Victoria, B. C., on March 5. He took a hurried trip across the United States, giving lectures at Seattle, Wash., Portland, Ore., Berkeley and Riverside, Calif., Boulder and Fort Collins, Colo., Manhattan, Kans., Chicago and Urbana, Ill., Columbus, Ohio, Washington, D. C., New Haven, Conn., Amherst and Boston, Mass. He sailed on May 2 on his way to London.

Mr. H. L. Seamans, Entomological Branch, conferred on February 22 with the officers of the Irrigations Division, Department of Interior, at Calgary, Alta., in connection with cooperation experiments for the coming year. Mr. Seamans gave addresses before the Agricultural Short Course, held under the auspices of the Experimental Farm at Lethbridge, Alta., on "Cultural Practices in Agriculture in Relation to Insects," and on "Sugar-Beet Insects," before the School of Agriculture at Raymond, Alta., early in February.

The following entomologists have recently visited the Gipsy Moth Laboratory or office at Melrose Highlands, Mass.: Dr. Arthur Gibson, Chief, Entomological Branch, Ottawa, Can.; J. T. Ashworth, in charge of Moth Work for the State of Connecticut; H. L. McIntyre, of the Conservation Commission of the State of New York; D. J. Caffrey and L. H. Worthley, of the European Corn Borer project; L. B. Smith and C. W. Stockwell, of the Japanese Beetle project, and W. A. Osgood, of the New Hampshire State Experiment Station.

Mr. R. T. Webber of the Bureau of Entomology, sailed February 20 on the S. S. Roosevelt for Cherbourg, France. His mission is a continuation of the investigations of the gipsy moth and brown-tail moth infestations in Europe. His trip will take him to France, Spain, Portugal, Northern Africa, Italy, Germany, Austria, Hungary, Czechoslovakia, Poland, and the Balkans. He will endeavor to establish temporary summer laboratories wherever he locates places suitable for obtaining natural enemies of the two moths just mentioned, for shipment to the Gipsy Moth Laboratory at Melrose Highlands, Mass. Mr. Webber will return to Melrose Highlands after having completed the season's work.

The collection of ants made under supervision of Prof. G. M. Bentley, State Entomologist, in the city of Memphis, Tenn., during the summer of 1925, is now in the hands of Dr. L. O. Howard, Chief, Bureau of Entomology, Washington, D. C., for determination. Systematic collections of ants in the city of Chattanooga has

been arranged for the summer of 1926. As these collections will represent the varied climate zones of the State, together with a collection from the mountainous districts which will also be made this summer, it is hoped that a list of the ants of Tennessee will be ready for publication this fall.

According to Mr. E. R. Buckell of the Entomological Branch, the Provincial Department of Agriculture has received many requests during the winter for aid in combating grasshoppers in the Peace River district around Pouce Coupe, Grande Prairie and Fort St. John. It is not known what species occur so far north. As an instance of the great value of grasshopper control work, Mr. Buckell reports that in 1925 (the worst grasshopper year in the history of British Columbia), vegetable and forage crops to the value of $500,000 were saved from destruction in the Kelowna and Vernon areas, B. C., at a cost of a little over $16,000.

On March 11 and 12 Dr. T. E. Snyder of the Bureau of Entomology, took part in an inspection of a section of a test-pole line of the American Telephone and Telegraph Company between Quantico and Fredericksburg, Va. Squared pine poles, after having been impregnated for their entire length with coal-tar creosote, by cylinder pressure process, were set, mostly in 1897. This is one of the oldest lines of creosoted poles in the United States. The very few failures due to insects or fungi were to be accounted for by season-checking which extended into the wood more deeply than did the preservative treatment. This pole line is still in excellent condition.

Mr. C. T. Greene of the U. S. National Museum, left early in March for Panama, where he will collect, rear, and associate larvae and adults of fruit flies for the Federal Horticultural Board. Mr. Greene's headquarters will be at Ancon, with Mr. Zetek. Fruit-fly larvae have been intercepted at quarantine many times, but, because they have never been carefully associated with the adults, it has been impossible to get specific identifications. It is expected that Mr. Greene's work in Panama will permit the association of the larvae and adults of the more common fruit flies of Central and South America. Mr. Greene will probably not return to Washington until the middle of June.

Dr. J. M. Swaine, Entomological Branch, states that recent additional reports received emphasize the seriousness of the injury apparently being caused by the European beech bark louse in the beech forests of Nova Scotia. This problem will be studied by the Division during the coming summer. Dr. Swaine has arranged with Professor H. P. Webb of the University of New Brunswick (Fredericton), and the Provincial Forester to carry out a joint planting program in which poplar and pine will be planted alternately in rows to secure the immunity of the latter from white pine weevil injury. Dr. Swaine gave an address on "The Wanderings of a Forest Entomologist," before the Toronto Field-Naturalists' Club on March 8.

Announcement of recent transfers in the Bureau of Entomology are as follows: W. E. Stone, Assistant Entomologist, from Tampa to Sanford, Fla., to engage in co-operative control experiments against the celery leaf-tyer; W. A. Stevenson, Florence, S. C., H. C. Young, A. J. Chapman, Tallulah, La., to Tucson, Ariz., Luther Brown, Japanese beetle quarantine work in Pennsylvania, to Deciduous Fruit Insect Investigations at Sligo, Md.; A. M. Vance, Charlottesville, Va., to Arlington, Mass., and will assist Mr. K. W. Babcock in his European investigations of the corn borer; Dr. F. H. Lathrop, Deciduous Fruit Insect Investigations, who was

stationed at Sanford, Fla. during the winter months, has returned to his permanent headquarters at Harrington, Me., where he will continue investigations of the blueberry maggot.

Mr. H. G. Crawford, Entomological Branch, Canadian Department of Agriculture, was absent from Ottawa in Western Ontario, February 22 to March 1, attending a series of meetings held in co-operation with the Provincial Department of Agriculture in its control campaign against the European corn borer. Addresses were given by Mr. Crawford at Adelaide Village, Harrietsville, Ilderton, Coldstream, Morpeth, Wallaceburg and Dresden. He visited Chatham, Ont., on March 15, to attend the second demonstration of the stubble beater developed by the International Harvester Company of Chicago to aid in the control of the European corn borer. The machine indicates great promise under certain conditions. Mr. Crawford gave an address on the "Entomological Service in Canada" before the Gyro Club, Ottawa, on March 31.

Mr. H. F. Bain, recently appointed assistant to the State Entomologist of Wisconsin, in cranberry insect and plant disease control, began his work in Wisconsin on February 15. A branch office is being established at Wisconsin Rapids with complete equipment for plant disease diagnosis and insect collection. In addition to field surveys for incipient insect outbreaks, Mr. Bain will give particular attention to forecasting the keeping quality of the berries, using methods recently worked out by the Federal Bureau of Plant Industry for this purpose. Before starting the branch office, Mr. Bain spent the winter at Washington, D. C., summarizing the results of his cranberry investigations on the Pacific coast, and then went to Madison, Wis., where detailed plans for the summer were worked out with Mr. S. B. Fracker, State Entomologist, and Mr. John D. Jones, Jr., Commissioner of Agriculture.

Mr. Arthur Gibson, Dominion Entomologist, attended the 13th annual meeting of the New Jersey Mosquito Extermination Association at Atlantic City, February 17–19, where he gave an illustrated address on the progress of mosquito work in Canada, and broadcast over the radio a brief statement on mosquitoes to the people of New Jersey. On February 17, Mr. Gibson visited the Gipsy Moth Parasite Laboratory at Melrose Highlands, Mass., where he occupied several hours with Messrs. Burgess, Collins, and other members of the staff. The following morning was spent at the Academy of Science, Philadelphia, particularly with Dr. Henry Skinner. On February 20, he visited the Japanese Beetle Laboratory at Riverton, N. J., and spent the following day in New York City, in the morning conferring with officers of the American Cyanamid Company, and in the afternoon visiting the American Museum of Natural History, to see especially the insect group exhibits recently installed.

Messrs. C. F. W. Muesebeck and R. C. Brown visited the U. S. National Museum the last week of February and sailed for Europe March 24 on the S. S. Republic. They are first going to the European Corn Borer Laboratory at Hyeres, France, where R. T. Webber will meet them after having completed the first part of his trip. He will then accompany them to certain gipsy moth infestations in Germany, Czechoslovakia, and Hungary. Mr. Muesebeck's work in Europe will be an intensive study of the gipsy moth, the brown-tail moth, and their parasites. Such an investigation will necessitate his stay in Europe for two or more years. The moth conditions will be investigated in several countries, with an intensive study in the

country where the gipsy moth infestation is best suited for these investigations. For the present his address will be Budapest, Hungary, care of the U. S. Consulate. During the summer Mr. R. C. Brown will assist Mr. Webber in his importation work, but will remain in Europe and assist Mr. Muesebeck during the winter.

Apicultural Notes

The East Tennessee Beekeepers' Association will hold a section meeting during the East Tennessee Farmers' Convention, May 19 to 23.

The Commissioner of Agriculture of North Dakota will issue no more permits for bees on the comb or used equipment to enter that state after July 1, 1926.

Mr. Virgil N. Argo has been granted a temporary appointment as Field Assistant of the Bee Culture Laboratory of the Bureau of Entomology to conduct investigations on the bee louse, *Braula coeca*, at New Windsor, Md.

The Seventh Annual Field Meet and Conference of the Wisconsin State Beekeepers, under the auspices of the University of Wisconsin, will be held at Platteville, with Mr. N. E. France, from August 17 to 20.

Mr. D. M. T. Morland, Assistant in Charge of Beekeeping of the Rothamsted Experimental Station, Harpenden, England, is visiting this country to study American beekeeping methods. His itinerary includes visits to the Bee Culture Laboratory, Washington, D. C.; Cornell University; The A. I. Root Co., Medina, Ohio; University of Wisconsin; University of Minnesota; University of Iowa; and Dadant and Sons, Hamilton, Ill.

Professor M. D. Farrar is now giving a course in beekeeping at the State College at Brookings, S. D. Twenty-five students were enrolled in this course last year. The College has two well-equipped laboratories and a lecture room for this course, and the apiary is conveniently located near the laboratory and is available for student use and observation.

Mr. W. L. Walling, State Apiarist, has revised the beekeepers' list for Tennessee and has 3,540 on the new list. Questionnaires have been sent out to all of these beekeepers and the data from these will be compiled in a bulletin at a recent date. Mr. Walling has sent out over 1000 letters of late to the beekeepers and to orchardists in regard to the Cole Bill now pending before Congress.

Recent visitors at the Bee Culture Laboratory of the Bureau of Entomology included the following: Mr. H. H. Root, General Manager of the A. I. Root Company, Medina, Ohio; Mr. Virgil N. Argo, of Cornell University, Ithaca, N. Y.; Dr. F. H. Lathrop, of the Bureau of Entomology; Dr. E. F. Phillips, of Cornell University; Mr. Frank C. Pellett, Associate Editor of the American Bee Journal, Hamilton, Ill.; Dr. N. A. Vappula, Entomologist of the Agricultural Institute, Tikkurila, Finland; and Mr. D. M. T. Morland, of the Rothamsted Experimental Station, Harpenden, England.

Dr. E. F. Phillips is sub-editor for apiculture of "Biological Abstracts", a journal for the abstracting of all biological literature, issued by the Union of Biological Societies. The first issue will appear in June 1926, and the office is in the Department of Zoology, University of Pennsylvania, Philadelphia, Pa. Dr. and Mrs. Phillips are planning to leave on June 2 for a trip to Europe, especially England, Scotland, France, and Switzerland, where Dr.Phillips will attend and address several meetings of beekeepers.

Notes on Horticultural Inspection

The State of Arizona reports the inspection of 8,371 automobiles during the month of March, 687 of which carried contraband material.

Mr. Sasscer of the Federal Horticultural Board recently made a trip to the Mexican Border and in company with Mr. Deputy, visited all of the Border ports as far west as Nogales.

Mr. O. K. Courtney has been transferred from the Washington office of the Federal Horticultural Board, to Providence, R. I., where he has been given charge of the work at that port.

Mr. I. T. Collins has been transferred from the Pink Bollworm Eradication work in Texas, to Seattle, Washington, to fill the position with the Federal Horticultural Board vacated by Mr. Forsell.

Mr. M. J. Forsell who has been employed by the Federal Horticultural Board since Oct. 16, 1924 as Junior Plant Quarantine Inspector with headquarters at Seattle, Wash., recently resigned to enter commercial work.

Dr. C. L. Marlatt, Dr. M. B. Waite and Mr. J. E. Graff, members of the Federal Horticultural Board, attended the Second Annual Flower Show of the American Orchid Society, on May 7, as guests of the President of the Society.

Mr. P. C. Brown reported for duty at Chatham, and Mr. J. G. McPharlin at Toronto, Ont., on March 30. They will assist the District Inspectors at those points until the rush of spring importations is over.

Brown-tail moth scouting in Nova Scotia has resulted in the finding of thirteen new nests, making a total, so far for the season, of 77 nests as compared with 154 last year during the same period.

Mr. H. C. Millender who has been employed for several years by the Federal Horticultural Board on the Pink Bollworm Eradication work, was placed in charge of the inspection work at the Port of Houston, Texas, on April 1.

The Federal Horticultural Board is preparing an exhibit for the Sesqui-centennial Exposition to be held at Philadelphia this summer, illustrating the different phases of work being carried on. The exhibit will be made up of photographs and a few Riker mounts.

Mr. J. M. Singleton of the inspection force at El Paso, Texas, was transferred to Washington, D.C., to assist at the Inspection House of the Federal Horticultural Board during the rush of spring work. He returned to El Paso about May 15.

The entomologists and nursery inspectors of the Southeastern States met early in February at Atlanta and organized the Southern Plant Quarantine Board with the following officers: R. W. Harned, Mississippi—President; W. E. Anderson, Louisiana—Vice-President; B. P. Livingston, Alabama—Secretary. This completes the organization of four regional boards whose object is to coordinate and strengthen the Plant Quarantine and Inspection work of the states.

Mr. R. E. McDonald, Chief of the Division of Entomology of the Texas State Department of Agriculture, made a trip recently to Tucson, Arizona for a conference on the Thurberia Bollweevil situation. Mr. B. R. Coad of the Bureau of Entomology, Mr. Oscar C. Bartlett, State Entomologist of Arizona, and Mr. T. S. Bishop, Chair-

man of the Arizona Commission of Agriculture and Horticulture, were present at the conference.

Mr. L. S. McLaine, Entomology Branch, gave an illustrated talk on entomology before an audience of about 800 school children at Ottawa, on February 13. He also gave an address on "Insect Foes from Foreign Lands," at a luncheon of the "Gastronomic Club," Ottawa, on March 3. On March 8–9, Mr. McLaine visited Montreal in connection with the erection of the new fumigation building. It was anticipated that the building will be completed some time in mid-April.

The Plant Conference Board of the Middle Atlantic and North-Eastern States, held its annual meeting in the American Museum of Natural History at New York, Mar. 10, 1926. Problems of immediate importance were discussed, including: The possibility of the introduction of the Alfalfa Weevil into the Eastern States; The situation with reference to *Anomala orientalis;* The inspection of export fruit and vegetables, with special reference to arsenical residue; The Potato Wart situation, and the control of the movement of potatoes to prevent the entry of tubers infested with the Potato Tuber Moth into commerce. Mr. J. E. Graff attended the meeting as the representative of the Federal Horticultural Board.

Several quarantines have recently been put into effect by a number of States as follows:

The Alfalfa Stem Nematode—
Utah.

The Alfalfa Weevil—
Michigan, Minnesota, Nebraska, New Mexico, Oregon and S. Dakota.

The Asiatic Beetle—
Connecticut.

The Black Stem Rust of Wheat and other Cereals—
Michigan.

The Chestnut Bark Disease—
Michigan.

The Cherry Fruit Fly—
California and Utah.

The Colorado Potato Beetle—
Idaho, Nevada and Utah.

The European Corn Borer—
Illinois, Iowa, Kansas, Michigan, Minnesota, Missouri, S. Dakota and Wisconsin.

The Japanese Beetle—
Michigan and S. Dakota.

The Oriental Fruit Moth—
Arizona, California, Idaho and Utah.

The Pecan Leaf Case Bearer—
Arizona and Utah.

The Satin Moth—
S. Dakota.

The Virus Diseases of Raspberry—
Michigan.

The White Pine Blister Rust—
New Mexico.

Notes on Medical Entomology

Dr. William A. Hoffman and Dr. Clay Huff, of the School of Tropical Medicine, Johns Hopkins University, Baltimore, Md., recently visited the Division of Insects, U. S. National Museum, to examine the collection of biting flies and to consult with Dr. Aldrich.

The exhibit of the Bureau of Entomology relating to insects affecting dairy cattle, poultry, and hogs, has been left in place on the demonstration train, which will cover the entire mileage of the Cotton Belt Railway throughout the States of Texas, Louisiana, Arkansas, and Missouri.

A mosquito campaign in Knoxville, Tenn., is now in progress under the direction of Prof. G. M. Bentley, Department of Entomology, University of Tennessee. Mr. Bentley has, in connection with his work, obtained the assistance of Dr. H. G. Haygood, City Health Commissioner, and his assistants. The object of the study will be to map the mosquito-infested areas of the city and suburbs of Knoxville. These specimens will all be classified and a campaign carried on to do away with the mosquito-breeding places. The Chamber of Commerce and the Boy Scouts are rendering valuable assistance in the collection, both of larvae and adults from all parts of the city and suburbs.

Pacific Slope Notes

Mr. Kenneth E. Gibson has been appointed temporary field assistant of the Bureau of Entomology, to be engaged in wireworm investigations at Toppenish, Wash.

Mr. C. M. Packard, of the Sacramento, Calif., laboratory, Bureau of Entomology, in company with Mr. Roy Campbell, visited the Antelope Valley in the last week of February, to inspect the burning operations with aphids, which are being conducted there.

Mr. Claude Wakeland, Entomologist of Idaho, visited the Bureau laboratory at Toppenish, Wash., February 19, and inspected the wireworm work conducted by Mr. M. C. Lane, in charge of the station. Mr. Wakeland and Mr. Lane arranged some experiments in control of wireworms, which Mr. Wakeland is planning to conduct at Parma, Idaho.

Mr. M. C. Lane visited the Horticultural Schools at Walla Walla and Clarkston, Wash., on February 5 and 6, and participated informally in the programs. At Walla Walla, about 100 vegetable and fruit growers were present, and at Clarkston about thirty of the same class of farmers were in attendance. They all displayed great interest in the wireworm and methods of controlling it.

On March 11 Dr. R. J. Tillyard, of the Cawthron Institutute of Scientific Research, New Zealand, and Mrs. Tillyard, called at the Forest Grove, Ore., laboratory, accompanied by Commissioner H. C. Atwell, of the Oregon State Board of Horticulture. On the evening of March 12 Mr. Atwell entertained Dr. and Mrs. Tillyard at dinner at the Congress Hotel, Portland. Other guests were Professor Don C. Mote, of the Oregon Agricultural College, Mr. Howard C. Stearns, who has been working on the tachinid parasites of the European earwig for the Oregon State Board of Horticulture, and Mr. L. P. Rockwood, of the Bureau of Entomology. Methods of handling the imported tachinid parasites of the earwig were discussed and Dr. Tillyard displayed some fine specimens of fossil insects.